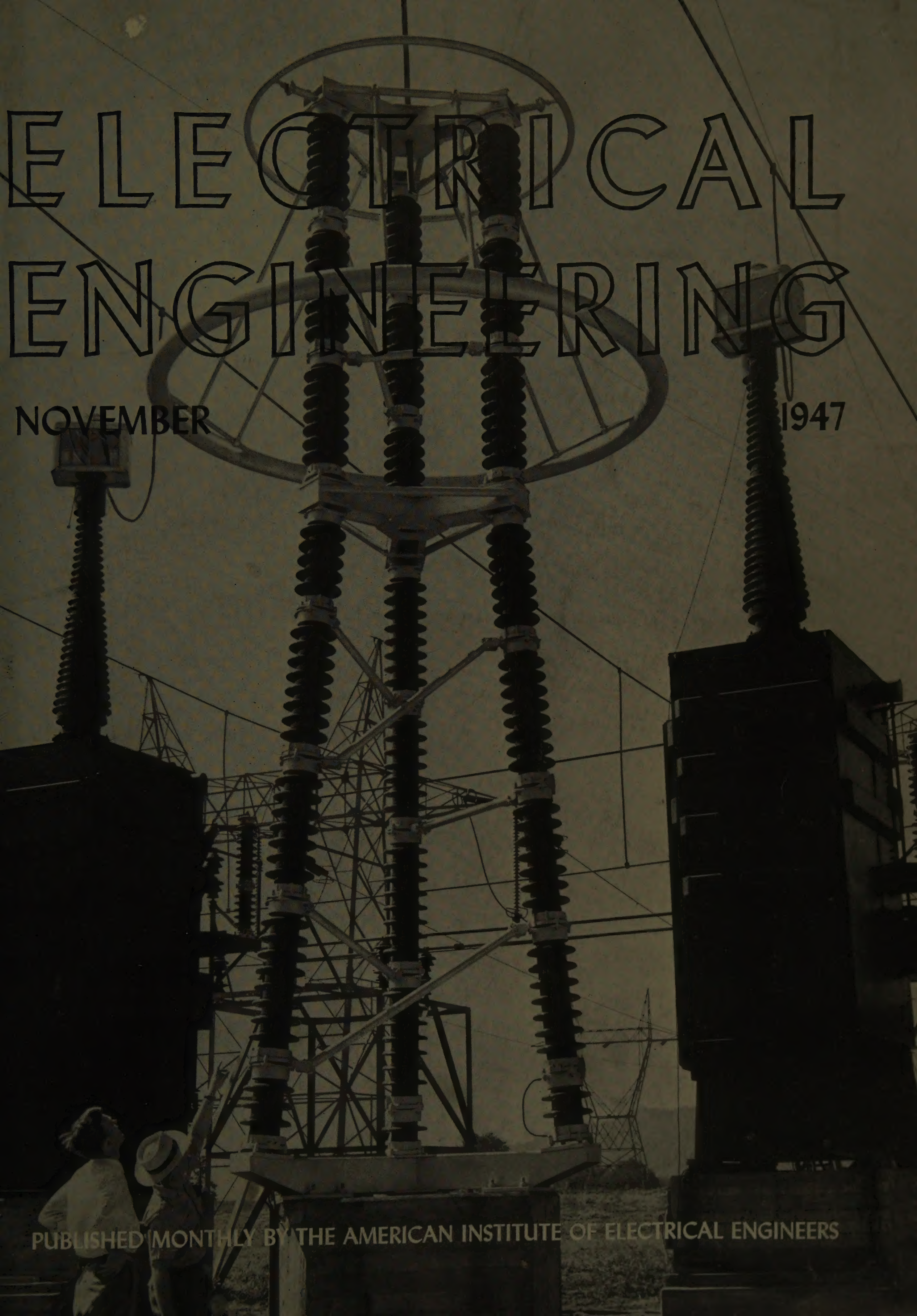
ELECTRICAL ENGINEERING

NOVEMBER 1947



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The Cover: World's largest self-supporting lightning arrester, constructed by the Westinghouse Electric Corporation for the 500-kv Tidd test line of the central system of the American Gas and Electric Company.

Westinghouse photo

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Electrical Engineering Graduate Studies Program of the California Institute of Technology

ROYAL W. SORENSEN
FELLOW AIEE

The California Institute of Technology has been indicated as a leader in the field of graduate work in electrical engineering, and thus a consideration of its pattern for such studies should be of profit. Some phases of the institute's program are presented, not because they are considered wholly unique, but because they are of considerable merit and did help to pioneer the way to a high standard of graduate work.

GRADUATE studies for electrical engineering students at the California Institute of Technology are primarily studies leading to the degree of doctor of philosophy in electrical engineering, with a somewhat lesser emphasis upon the professional degree, electrical engineer. Aeronautical, civil, and mechanical engineering graduate studies follow about the same pattern, with more professional degrees granted in those courses than in electrical engineering.

The arrangement of the courses of study, the standards of scholarship, and the admission requirements for all graduate students in all departments are administered by a committee on graduate studies which also selects all students admitted to the college to study for the master's degree. All programs of study and admission to candidacy for the engineering master's degree are in charge of the committee on courses in engineering which passes upon the rights of study continuation and makes recommendations for or against graduation for all engineering students studying for bachelor's or master's degrees.

As it is the common practice of the institute to admit students seeking their first admission to graduate studies to studies leading to the master's degree, this plan works well in several ways. It provides for a good plan of transition from undergraduate to true graduate status, and affords a way to add that much desired fifth year to the engineering curricula without depriving engineering students of the bachelor of science degree for the completion of 4-year courses, or subjecting them to the experience of receiving second bachelor's degrees for the completion of 5-year courses. The plan permits the faculty to have contact for a year with the students who wish to do advanced graduate work before having to pass upon their abilities to carry on regular graduate studies programs. All students who have obtained any degree at the institute must make application for admission to study for any other degree and must be considered as students enrolling for the first time.

The fifth year courses are taught in much the same manner as the junior and senior courses. At least 20 per cent of all fifth year curricula, like those of the preceding four years, must be selected humanities. There are a number of these courses from which the students may choose. For an electrical engineering student, one half the fifth year curriculum chosen will be prescribed electrical engineering subject matter (Table I). For the normal student, the remaining portion (between one fourth and one third of the total) will be approved electives. These may be mathematics, engineering, or science courses. This plan of granting the master of science degree without a thesis is not approved by all educators, but observation of the performance after graduation of the men who have master of science degrees provides convincing evidence that the lack of a thesis has not resulted in degree holders who are not entitled to a degree. The plan does not preclude earning a master of science degree via the thesis route when qualified students have in mind a worthwhile project that will produce a suitable thesis.

The California Institute of Technology graduate studies pattern, though its true graduate work applies only to work for the higher degrees, cannot be discussed without some consideration of not only the fifth year studies, but also the bachelor's degree studies. The declared policy of the school is that it is a college incorporating the strongest possible research program, rather than a research institute with an educational department. Faculty members quite often simultaneously or interchangeably teach graduate and undergraduate courses and also carry on research. Graduate students holding graduate assistantships teach undergraduate and fifth year students, very often with a proficiency not always equaled by regular faculty members. Fifth year engineering students and students working for the engineering and doctorate degrees arrange curricula well interwoven with the curricula of students majoring in science. Indeed, the undergraduate curricula for applied physics students and electrical engineering students have much in common throughout the four undergraduate years. Furthermore, the electrical, mechanical, and aeronautical students have identical courses through

Essential substance of a conference paper presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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the junior year (see Table II), and the civil engineering students have done about all of that common work by graduation.

DOCTORATE DEGREE REQUIREMENTS

The general requirements which must be met by students working for doctorate degrees include

1. Breadth of scientific attainment.
2. Power to investigate scientific problems independently and efficiently.
3. Research and thesis.
4. Satisfactory grades in systematic studies of advanced character in science and engineering preceded by certain specific courses.
5. Power of oral and written expression.
6. Reading knowledge of two foreign languages; German, French, or Russian.
7. Minimum graduate residence of three years with at least the last one at the institute.

Specific Courses for Doctor's Degree in Electrical Engineering. To be recommended for candidacy for the doctor's degree in electrical engineering, the applicant must pass the following subjects with a grade of *C* or better:

Electricity and magnetism (27 units)
Engineering mathematical physics (45 units)

and one of the following subjects:

Analytical mechanics (36 units)
Applied mechanics (48 units)

and one of the following subjects:

Introduction to mathematical physics (36 units—Ph 5)
Introduction to mathematical physics (45 units—Ph 6)
Engineering mathematics (27 units)
Methods of advanced calculus (10 units)
Differential equations (10 units)

and 30 units from the following:

Advanced electric power system analysis (36 units)
Dielectrics (6 units)
Circuit analysis (27 units)
Electromagnetic fields (27 units)

When the student has completed those requirements and has been admitted to candidacy, he should

1. Show ability to solve almost any problem relating to electrostatics or steady current flow in extended media involving purely conducting or purely insulating boundaries in the rectangular, cylindrical, spherical, or spheroidal co-ordinate systems.
2. Be able to devise conformal transformation for 2-dimensional problems that will solve most problems involving rectangular boundaries and right angle bends, such as the increase in resistance and distribution of local heating due to a crack in a bus bar, or the increase in a multiplate parallel plate capacitor due to variations in the field near the edges.
3. Know how to solve eddy current problems with simple geometrical boundaries as, for example, the forces acting on a magnet moving near a conducting sheet or the effect on the self-inductance and resistance of coils placed in shielding metallic cans, and determine the strength and distribution of the external fields.
4. Be familiar with the solutions of Maxwell's equations in all the common co-ordinate systems and with their applications to transmission lines, antennas, wave guides, and cavities.
5. Be able to attack intelligently problems involving these equations for which there are no answers in the handbooks.
6. Be able to use general theorems, such as those of Gauss and Green, to transform unfamiliar problems into familiar ones.

"Electricity and magnetism," a 9-hour-per-week course for one college year, is the crucial course for developing and testing the student's qualifications for attaining the specified abilities. "Engineering mathematical physics," a 12-hour-per-week throughout-the-year course, is provided to open the way to apply the techniques learned in "electricity and magnetism" and preceding courses to practical engineering problems.

Time Required. The minimum required college residence time for the doctorate degree is three years subsequent to receipt of the baccalaureate degree, with a minimum of one year of residence at the institute. So far the minimum residence of any student at the institute who has obtained the doctorate degree has been two years.

Degrees Granted. The institute granted its first doctorate degree, in physics, to an electrical engineering student in 1924. This was followed by a second similar degree in 1926, but since that time the doctor of philosophy degree in electrical engineering has been awarded. The recipients of these degrees quite frequently have been men who, as undergraduates, majored in physics. Also, undergraduate electrical engineering majors have obtained physics doctorates.

Present Postwar Enrollment. For the 1946–47 year, 50 students have been enrolled for studies leading to the master's degree, most of whom will obtain the degree with one year of residence. An equal number is admitted for 1947–48. Thirteen of the present 50 obtained the bachelor's degree at the institute, and two of the six electrical students now enrolled for work beyond the fifth year obtained degrees at the institute. Thirteen of the present 50 fifth year students have been admitted to studies leading to the doctorate degree. This number, though larger than for any preceding year, is still about one fourth of the fifth year group, which is the same fraction of the fifth year group as continued for doctorate work before World War II.

Standard Criteria for the Student. Great care has been taken to admit for doctorate studies only students with high analytical ability and/or extraordinary experimental technique, and who show promise of making real contributions to the profession rather than just doing a large amount of standard engineering well. The number admitted is limited to the few that the staff can supervise carefully. This procedure does much to guarantee that an electrical engineering doctorate will be a man well enough acquainted with physics and mathematics to feel at home in the company of specialists in those fields.

The Thesis. The doctorate thesis is, of course, the im-

portant part of any doctorate degree achievement. The electrical theses to date have covered a wide range of subjects and the majority of them have been developed experimentally. A few theses, mostly by students from countries other than the United States, have been entirely analytical, however. Some of the theses researches would be very acceptable as physics doctorate theses. The electrical features of these theses concern the instrumentation involved in the researches.

Theses researches are carried on during the summer quarter as well as during the college terms. The institute normally does not hold summer classes but the faculty operates on a yearly basis, conducting its own researches and aiding the students in their work. No tuition charge is made for summer use of laboratories but full credit is allowed for research during that time.

Professional Degree Requirements. The professional degree requirements are as rigorous with respect to quality as those of the doctorate degree. The difference is the minimum graduate residence time requirement of two years for the former as compared with the 3-year doctorate requirement, and a reduction of the amount of advanced physics courses required. The specific requirements are those listed for the doctorate degree with the physics courses, "electricity and magnetism," omitted.

Every possible effort is made to prevent the professional degree from becoming a degree granted to students who try for a doctorate degree and fail. In general, students are not encouraged to enroll for the professional degree in electrical engineering, but the other engineering divisions, particularly the aeronautics group, find the professional degree very useful and grant a considerable number.

Research Facilities. Students engaged in research are given access at all times to facilities required for their work. These are not only good laboratories and libraries, but also well-equipped student shops where students may construct equipment for which their technique qualifies them, as well as shops manned by skilled mechanics for construction requiring more skill than possessed by students.

The special research facilities for electrical engineers at the institute include the high-voltage laboratory, the analogue computer laboratory, and the electronics laboratories. These laboratories are not isolated either by location or organization, but are closely related and interoperative with the other engineering and science laboratories. For example, some of the electrical student research rooms are in the building that houses the nuclear physics group. The electronics and analogue computer laboratories are in the physics laboratory buildings and are surrounded by research rooms occupied by physicists engaged in their particular type of researches. The physicists often use the high-voltage laboratory. The civil and mechanical engineers have used some of its equipment. A number of electrical engineering graduate students are engaged in researches where their training and interest makes them valuable in developing electrical means for measuring phenomena encountered in aerodynamic, hydrodynamic, and mechanics problems.

Laboratories and shop facilities, no matter how perfect, do not guarantee high quality graduate courses and research programs. Their quality is determined by the personnel of the faculty. The institute has been fortunate in that respect. Its policy was initiated in 1908 when the late Doctor George Ellery Hale joined the board of trustees of Throop College of Technology with the provision that the trustees change its operation as a technical institute to that of an engineering college similar to the Massachusetts Institute of Technology. However, he suggested two points of difference: a large portion of humanities in the curricula, and a stronger emphasis on the basic sciences than was included in the engineering curricula of most colleges and universtities.

The Engineering Doctorate and Industry. For several years industry seemed in doubt as to the value of the engineering doctorate degree even though its research staffs were made up largely of science doctorates. This doubt was expressed by the lack of a willingness on the part of industry to make the starting pay for engineering doctorates larger than for men with the bachelor's degree only. Or if it were made larger, the increment above the bachelor's pay was very small. The Bell Telephone Laboratories organization was a notable exception and thereby obtained some very valuable men. Since about 1934, however, the attitude of industry has changed, and quite generally recommended doctorates find their starting salaries about 50 per cent greater than that of the holders of bachelor's degrees. Indeed, at the beginning of this change of opinion, one representative of a large employer of college graduates expressed publicly high regard for California Institute of Technology engineering doctorates and made an apology for having underrated the value of engineering doctorate training. A continuation of that high regard is something to be maintained zealously. As the regard is based upon the performance of engineers who have included much work in mathematics and physics in their doctorate programs, care must be exercised to continue doctorate programs that do not revert to so much engineering as to cause a reduction in the amount of science and mathematics students may study.

The reluctance of industry to agree with the institute on the doctorate degree value in those earlier years is quite understandable. Some engineering doctorates who were employed were found less qualified than many bachelors for the work to be done. Under such conditions management of course had to make embarrassing adjustments. Improper doctorate standards, or failure on the part of industry and college to agree as to

Table I. Fifth Year Engineering Curriculum

Course	Units Per Term (Three Terms)
Humanities electives	9 or 10
Advanced electric power system analysis	12
A-c laboratory	6
Circuit analysis	9
	36 or 37
Electives	12
	48 or 49

what may be expected of the doctorate educational program, bring about such conditions.

Engineering Education Postwar II. Engineers and scientists as a result of the war have attained public acclaim and much long desired professional recognition. Indeed the swing of public sentiment almost has overshot a good balance. To avoid a swing to low repute, great planning care is required. The present problem is very complex. Some of the factors to be considered are

1. The men who made early electrical engineering were not educated in engineering colleges. They were men trained in science or in the "school of hard knocks."

2. The men who made 20th century engineering have been largely the product of engineering colleges. They have been taught manual dexterity, the use of simple mathematics and elementary physics in solving not very complicated engineering problems, and the use of handbooks written by leaders in the profession.

3. The world wants more engineering so there is, at present, an apparent shortage of engineers. At the same time, the walls of engineering colleges figuratively are bursting because of the large number of students, while outside the walls a larger number is trying to get in.

4. Many are inclined to think that there is magic in taking graduate work, and far too great a share of them think graduate work means more work similar to the undergraduate work.

5. There is much equipment for laboratories available at little or no cost.

6. There is a great shortage of experienced teachers of electrical engineering, particularly teachers with a background of experience plus advanced training in physics and mathematics.

In trying to account for all these factors, one should not forget that large laboratories do not guarantee valuable research programs. The California Institute of Technology program grew around men and not laboratories. The men conceived the lines of research to be followed and, in most instances, from humble and limited beginnings acquired laboratories. The pressure for graduate work should not lower the tone that has gained respect for that work.

The emphasis that has been placed upon mathematics, basic science, and humanities obviously reduces the college time that may be devoted to engineering studies unless the residence time is increased. How long that residence may be profitable must be determined by each individual. Some of the determining parameters are the student's age, his ability to continue his interest in college life, and his financial status. The average graduate residence of the institute electrical engineering doctorates has been about four years.

The average age of engineering doctorate under 30 is about 26.3 years. This probably will increase a bit until the effect of the war is over. In general, it seems highly desirable for men to attain their doctorate degree before they are 30 years old. If they are in the upper 20's they should have had, prior to the receipt of the doctorate degree, some practical engineering experience.

This article should not be construed as criticizing in any way the excellent education program conducted by the colleges up to the present time. Colleges have met the demands of industry well, but these demands probably have forced an overemphasis on the manufacturing, design, and operation techniques of apparatus at the expense of a proper devotion to the fundamentals underlying those techniques. The fact that the techniques were developed around the scientific discoveries and laws pronounced by men like Faraday, Henry, Kirchoff, Maxwell, Steinmetz, and others, must not be overlooked. However, having gone through the required cycle of practical developments based upon the vistas these men opened with the resultant devices now available for our use, if we are to meet the engineering demands of the future we must return to a deeper study of the basic sciences. To do this well curricula must be rearranged to reduce the number of special courses and curricula options, and to teach the students to know that the basic courses are not pre-engineering courses to be passed and forgotten, but are a part of the profession of engineering. Indeed, one of my pet idiosyncrasies is that some day men will not be called civil, electrical, or mechanical engineers by virtue of words on a college diploma, but will be classified professionally by their occupation. Perhaps an anecdote will illustrate my meaning.

A former electrical engineering student, when an electrical engineering faculty member, happened upon several members of the mechanical engineering staff of the college where he taught. These professors were discussing a rather complicated thermodynamics problem and their lack of ability to solve it. The former student, always interested in anything involving mathematics, asked about the problem. The next day he

Table II. Third Year Engineering

Electrical, Mechanical, and Aeronautical Students

Course	Units Per Term (Three Terms)
Introduction to literature	8
Applied mechanics (dynamics, strength of materials)	12
Basic electrical engineering	6
Basic electrical engineering laboratory	3
Engineering mathematics*	9
Thermodynamics and fluid mechanics	11
	49

* Students with scholastic records that warrant the excess load may take "introduction to mathematical physics" (12 units) as an alternate for "engineering mathematics."

brought in a correct solution, whereupon one member of the group said, "I thought you were an electrical engineer, not a mechanical engineer." His answer was, "The logic in both fields is the same. The only difference is that the characters in the equations represent for the two fields different phenomena." When engineering education produces more students with that attitude, we no longer need worry about professional recognition.

Perhaps the ideas I have tried to convey in this article are provincial and too limited. My teaching experience all has been in one college. However, during World War II it fell to my lot to aid in assembling a group of men charged with producing new war equipment that involved pioneering in undeveloped engineering fields. When the problems were entirely new, particularly when they involved complicated analysis, the several groups seemed to show that men educated as physicists could solve these new problems more readily than men trained as engineers, and quite often could solve problems the engineers were unable to solve. If those impressions are indicative of the present engineering demands, our engineering education should not try to teach men about special devices but should provide for a thorough training in the basic sciences, citing typical engineering applications as much as possible. Such a program will place the burden of special engineering education upon industry where it belongs and where it should be done better than is possible in college. It is unreasonable to expect college professors to keep up with the many rapid industrial developments continually taking place.

In justice to engineers, we should not fail to note that a lot of the war work done by physicists would have been done with much less difficulty if the physicists, in turn, had been better acquainted with engineering practice.

Electronic Stabilizer for Power Transmission

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An electronic stabilizer varies a reactive load electronically to maintain desired voltage and line current in a transmission line. The electronic stabilizer acts upon the transient reactance and therefore it has the fast response needed to increase the stability of long transmission lines.

THE LIMITATIONS of conventional synchronous power transmission are well known. It has been pointed out that most long distance transmission lines operate at a load corresponding to surge impedance.[1,2] This is the loading where the inductance and capacitance of the line neutralize each other so that the voltage remains constant throughout the line. Voltage regulation of an alternator historically has depended upon variation of the field current, and high-speed regulators have been developed in order to improve synchronous stability. This article describes a voltage control brought about by varying the output current. A reactive load is connected to the generator terminals. This load is varied electronically in such a way as to maintain the desired voltage and line current. Whereas regulation by field control is limited by the long time constant of the field winding, the electronic stabilizer acts upon the transient reactance and therefore it has the fast response needed to increase the stability of long transmission lines.

In its function it is analogous to a synchronous condenser because it is used to regulate the voltage at the point where it is connected by drawing a controllable current from the line.

ANALYSIS

With fixed excitation the conditions for stability limit are shown in Figure 1. As the load motor (or equivalent) pole axis lags behind the generator pole axis by the angle θ, the vector difference $\boldsymbol{E}_D$ of effective voltages follows a circular locus. The current follows a similar locus. Neglecting circuit resistance, current $\boldsymbol{I}$ has the greatest projection on voltage $\boldsymbol{E}_g$ when $\theta=90$ degrees. For greater angular lag, restoring torque as measured by $\boldsymbol{E}_g\boldsymbol{I}\cos\theta/2$ is less and the load falls out of step.

Corresponding to this condition, the difference voltage may be considered as divided into fractions, 0–1 the drop corresponding to the generator armature reaction, 1–2 the drop across the generator transient impedance, 2–3 line drop, 3–4 load transient impedance, 4–5 load armature reaction. Quantities E_2 and E_3 are the voltages actually seen by voltage measuring devices at the

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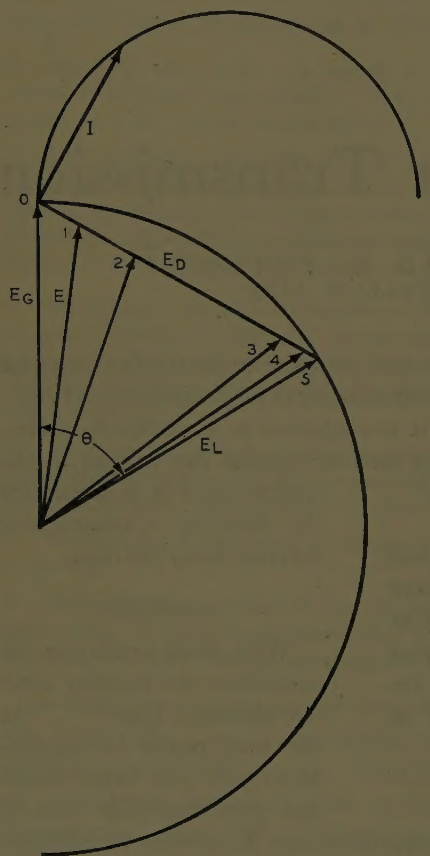
Ernst F. W. Alexanderson is consulting engineer and David C. Prince is vice-president in charge of electrical engineering department, General Electric Company, Schenectady, N. Y.

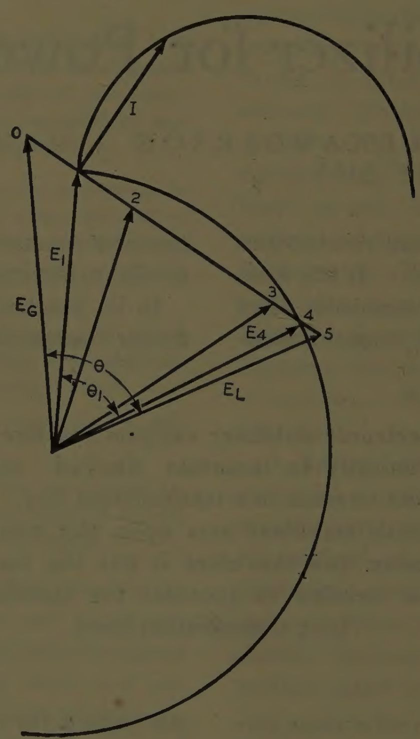
machine terminals. For short lines E_2 and E_3 are approximately 0.7 times E_g and E_L. The validity of the diagram presumes no correction in excitation during a transient variation in θ. For the diagram ideal round rotor machines are assumed.

If excitation response is fast enough to hold E_1 and E_4 constant during a transient, then the stability diagram takes the form of Figure 2. The angle θ at pull out is now greater than 90 degrees but the angle θ_1 between the maintained voltages is 90 degrees. Quantities E_g and E_1 have now considerably greater numerical values, but these are not real voltages. They are the voltages that would exist at no load with the same excitation and with no saturation. The demagnetizing effect of the load current results in only the voltages E_1 and E_4 actually being induced. Under transient conditions the inductance coupling between field and armature tends to maintain these generated voltages and so the regulator must be only fast enough to support currents already set up by transient currents.

Following this reasoning one step farther, if we can maintain the magnitudes of E_2 and E_3, the stability diagram becomes Figure 3. The stability limit now corresponds to the angle $\theta_2 = 90$ degrees. The generated voltages E_1 and E_4 exist but the difference between them and terminal voltage is absorbed as drop in the machine's transient reactances.

In the past, efforts have been made to introduce a





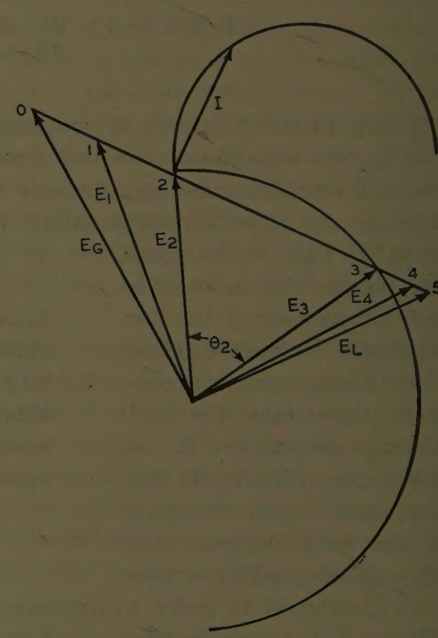


Figure 1 (left). Fixed excitation
Figure 2 (center). Regulated excitation
Figure 3 (below). Regulated terminal voltage

corresponding change in the generated voltage E_1 and E_4 by an increase in field current, but such a change takes place so slowly that very little improvement in stability has been realized above that corresponding to holding E_1 and E_4 constant. The proposed system of control consists of carrying continuously a dummy inductive load on the generators so that the field strength needed to meet the transient already is established. It is the function of the electronic stabilizer to check the current flow in the dummy load so that the higher voltage inherent in the generator is impressed on the line terminals without any delay.

Without the stabilizer, the system would fall out of step when the angle of E_1 and E_4 exceeds the critical angle because an increase of phase angle would reduce the voltage so that the torque reaction of the generator shaft would be reduced and the change would become accumulative. With the stabilizer the opposite happens. A swing toward larger phase angle causes the electronic control to reduce the wattless dummy load so that the voltage increases. This, in its turn, causes the torque reaction on the shaft to increase so as to restore the normal phase angle. An artificial synchronizing force thus is introduced which when added to the natural synchronism force, makes it possible to carry higher load.

TEST EQUIPMENT

Figure 4 represents the model test setup used for studying this method of operation. It consists of a generator, a motor, an artificial transmission line, and an electronic stabilizer. The latter is a short-circuited phase con-

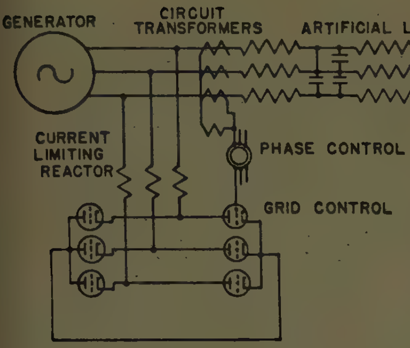


Figure 4. Electronic stabilizer for power transmission test equipment

trolled rectifier combined with current limiting reactors. The grids are controlled from current transformers in the line conductors at the generating end.

The vector diagram, Figure 5, shows the relationship of currents and voltages of the line, the generator, the stabilizer, and the motor. The line has an electrical length of 630 miles equivalent to 67 electrical degrees at 55 cycles. It can be operated reliably at a phase displacement of 60 degrees between terminals. At this load the current is leading at both ends. If there is a swing of phase angle due to a shock on the system, the power flow will increase with increasing phase angle and thus reacts as a synchronizing force. In ordinary synchronous operation, the synchronizing force is produced by an increase of current. In this case, however, the current is nearly constant because the line resonance gives it an effect approaching infinite impedance. A synchronizing force, however, is produced for two other reasons: the line current which at normal load was leading swings into phase; and the electronic stabilizer draws less current so that the voltage increases. The practical conclusion is that a long line should be operated a littel below surge impedance load. Further refinements of control may make the margin negligible, but the results obtained by the sample equipments are in themselves very encouraging.

The use of the electronic stabilizer can be approached from two points of view. One is as an adjunct to a conventional system with natural stability in order to increase the effective stability and to carry more power. The other is to use the stabilizer as a necessary part of a long transmission line system which has low natural stability but is designed to depend upon the electronic stabilizer for its operativeness. The latter point of view is the more interesting. Our model test equipment was set up to explore this case, and, therefore, an artificial transmission line built with an electrical length of 630 miles. The tests were made at 55 cycles because of the speed of motors that were readily available, but it may be said that this choice of frequency has the advantage of being close to both of the important frequencies of 50 and 60 cycles. A generator of 5-kva rating was operated with a line loading of 6 kw, whereas an alternator of a 15-kva rating was used to represent a large receiving system with other sources of power.

The following are the constants of the test equipment which was operated at 250 volts:

Artificial line

Three coils with a total inductance of 0.037 henry.
50 microfarads in delta between coils 1 and 2.
50 microfarads in delta between coils 2 and 3.

Generator

Synchronous impedance 12.5 ohms.
Transient impedance 1.4 ohms.

Motor

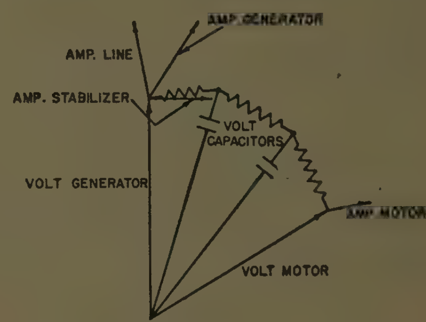
Synchronous impedance 2.5 ohms.
Transient impedance 0.6 ohm.

Stabilizer

Reactor in series with stabilizer 0.024 henry.
The tube equipment connected through a step-up transformer of 2-to-1 ratio.

Figure 6 shows the characteristics of the generator with stabilizer at varying loads. In this case the excita-

Figure 5. Electronic stabilizer for power transmission vector diagram for test equipment



tion is fixed and the phase control of the grids is fixed except for the automatic action of the current transformer. It should be noted that the stabilizer maintains substantially constant terminal voltage but that the voltage rises at high load when the grid control becomes effective. The fact that the voltage rises instead of drops, as it would without the stabilizer, gives the system an artificial synchronizing force.

Figure 7 shows the same characteristics with regulation applied to the generator field and the phase control of the grids. The grids are regulated so as to maintain constant terminal voltage up to full load, after which the voltage is allowed to rise at overloads. The field is regulated so as to maintain constant current in the stabilizer.

SYNCHRONIZATION

The artificial synchronizing force differs in its action from the natural synchronizing force. The oscillogram, Figure 8, shows the process of synchronization. When the line switches are closed, the system synchronizes promptly with a current swing which only slightly exceeds the normal. It was observed that before synchronization the generator was running four per cent faster than the motor. During the process of pulling

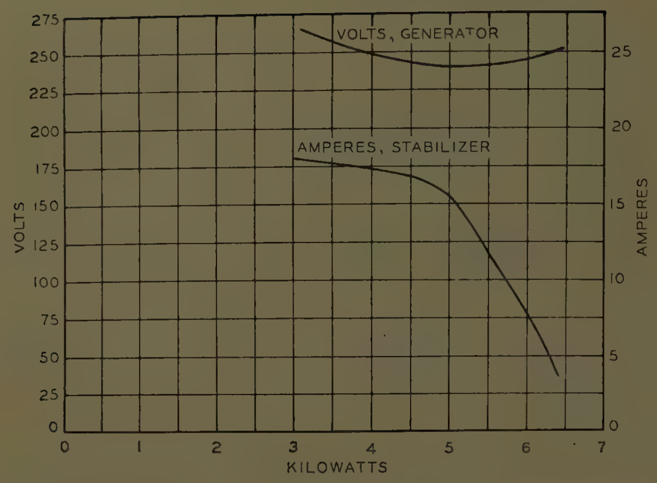


Figure 6. Characteristics—fixed field and fixed grid control

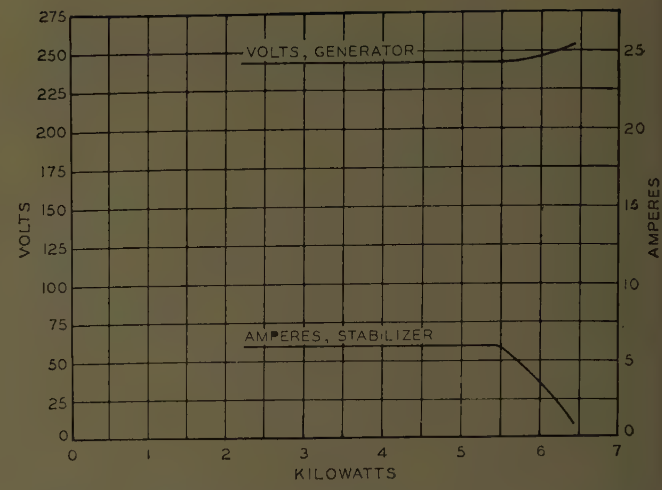


Figure 7. Characteristics—regulated field and regulated grid control

into step, the stabilizer acts as a commutator increasing the power flow when it is in the right direction and decreasing it when it is in the wrong direction. The oscillogram, Figure 9, shows currents and voltages of full load operation.

GRID CONTROL AND WAVE SHAPE

For those who are not familiar with power electronic devices, an explanation may be in order to show how the grid control serves to regulate the current in the wattless dummy load.

In an ordinary rectifier the voltage can be controlled by retarding the phase of the grids so that 90-degree phase retard reduces the rectified voltage to zero and no appreciable current flows even if the rectifier is short-circuited. The stabilizer operates in substantially the same way with the difference that the usual reactance in series with the d-c terminals is eliminated in order to speed up the action. Conversely, the reactance in series with the a-c terminals is greater than the usual one so that the maximum current that can flow is limited to a moderate overload.

The oscillograms show a harmonic distortion of the current flowing through the stabilizer. The harmonics are mostly the 5th and 7th because a 6-tube circuit was used. In practice, the tubes will be used in groups of 12 and so connected that these harmonics are eliminated. The 11th and 13th harmonics may be eliminated in a similar way by 24-phase connection, but this may not be necessary because the reactance is so much higher than in ordinary rectifier circuits.

SIZE OF STABILIZER

A question that must be answered is what is the proportion between the kilovolt-amperes of the stabilizer and the kilowatts of the transmission line. Our tests indicate that the kilovolt-amperes of the stabilizer need not be more than 50 per cent. The model system can be operated with 25 per cent kilovolt-amperes, but the higher ratio has greater margin of safety. The following analysis may explain these findings.

Due to the interaction of inductance and capacitance of a long line, the current in the transmitting end follows the voltage in the receiving end by phase as well as am-

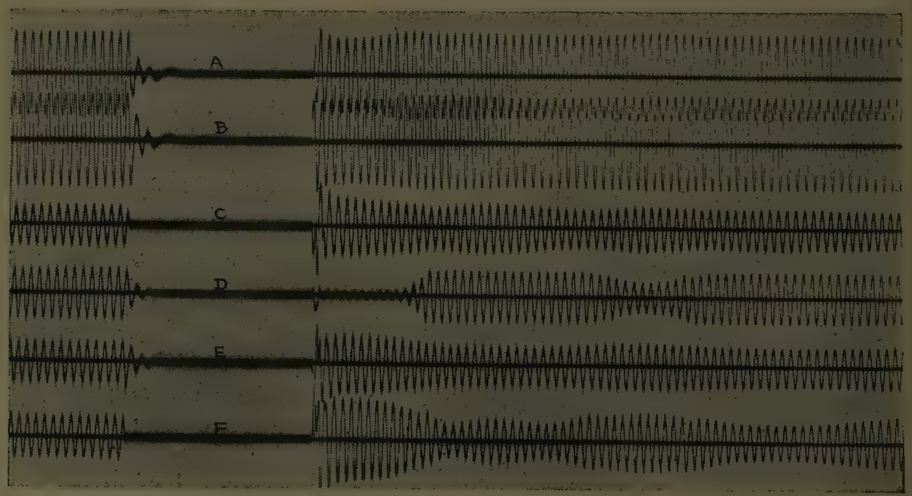


Figure 8. Oscillogram showing synchronization

A—Volts generator
B—Volts receiver
C—Amperes receiver
D—Amperes stabilizer
E—Ampere line
F—Amperes generator

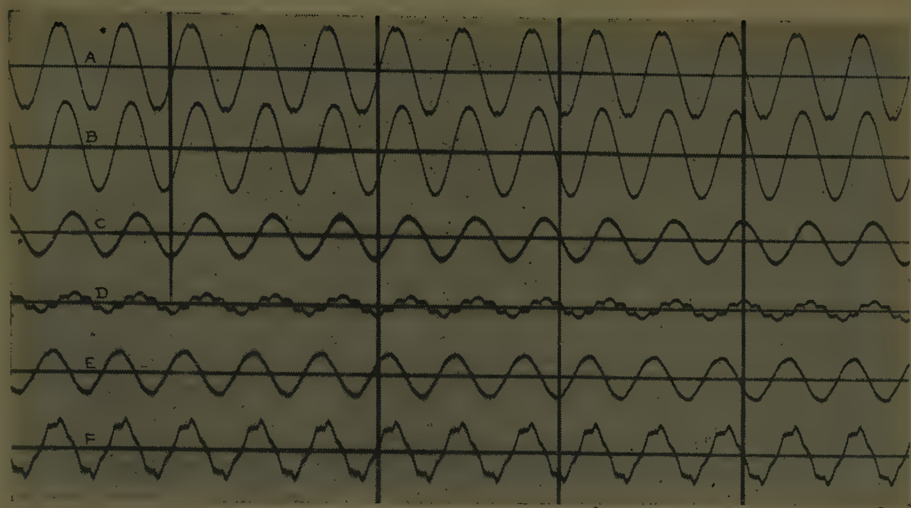


Figure 9. Oscillogram of full load operation

A—Volts generator
B—Volts receiver
C—Amperes receiver
D—Amperes stabilizer
E—Amperes line
F—Amperes generator

plitude. Therefore, if there is a swing of phase angle of plus or minus 15 degrees between the transmitted voltage and the received voltage, we can expect the transmitted current to swing plus or minus 15 degrees relative to the transmitter voltage. The normal current is of substantially unity power factor, and the phase swing of the current can be represented by the addition of a wattless dummy load swinging plus or minus 25 per cent of full load current. This wattless component is absorbed by the stabilizer. But we must do more than compensate for the phase variation of the current. We must overdo the compensation so as to create an artificial synchronizing force. We therefore may regulate the system so that 15-degree phase displacement causes the flow of a 50 per cent wattless current.

THE FUTURE

This article has been presented in order to suggest a new approach to an old problem—the extension of electric power transmission. It is less radical than d-c transmission. The electronic equipment may be of a type with which we have many years experience in the Carnegie Illinois frequency changer. No pretense is made of treating this subject exhaustively or to make economic or technical comparisons with other known methods of extending a-c transmission. Those other methods are, specifically, intermediate synchronous condenser stations and series capacitors. When to these we add the electronic stabilizer, we have three methods which all differ in principle but, nevertheless, may be used in combination. Whether the new method will compete economically in operating characteristics with other methods is for the future to determine.

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Fundamental Properties of Metals

Although great progress has been made in obtaining a sound general knowledge of the forces that hold matter together, scientists up to now have not been able to extend this work to three important classes of materials: the complex substances such as proteins that constitute living organisms; atomic nuclei; and metals and alloys; according to Professor Linus Pauling director of the Gates and Crellin laboratories of chemistry at the California Institute of Technology.

Speaking before the Southern California section of the American Chemical Society, he pointed out that application of a recently formulated equation has indicated that metallic atoms are bound to one another by electrons which they share. A similar mechanism provides the binding forces that govern the mechanical properties of organic materials such as fats and wood.

Interpretation of metallic structure in accordance with the new equation provides a qualitative explanation of many of the properties of some of the most common metals. It is found that atoms of chromium, tin, and manganese exist in two forms, small atoms with high combining powers, or valences, and large atoms with low valences, and in many metals each atom is attached to some of its neighbors by strong bonds and to others by much weaker links. The association of metallic valences with interatomic distances and properties of crystals has led to the construction of a reasonable satisfactory theory, however the whole treatment is essentially empirical in nature.

Engineering Education

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FOR THE PAST several years there has been considerable discussion concerning the 5-year engineering curriculum, and during that time several schools have adopted such a curriculum. The proposal to be presented in this article is a suggested alternative to the 5-year curriculum, and it is believed that it overcomes certain disadvantages of such a curriculum—namely, the stereotyping of the cultural subjects into such a mass-production plan that enthusiasm would be stifled for a majority of the students who might relish the opportunity of studying some cultural subjects.

The proposal is that the engineering curriculum proper be made a 3-year curriculum, the three years to correspond to the present sophomore, junior, and senior years. Entrance to the first year of the proposed curriculum is to be by examination. This examination is to cover whatever preparation in mathematics, English, speech, physics, engineering drawing, and other subjects that the engineering faculty may deem necessary. The examination will be given to all candidates regardless of origin, and as far as the engineering division is concerned, the candidates may make preparation by means of their high school training, college training, or individual study. It would not eliminate, however, the first year of college as a requirement, because the college in its application of the plan still could require a minimum number of credits (largely unspecified as to subject material) preliminary to a 3-year professional curriculum. The principal advantage to the school is that all engineering students would have a basic minimum preparation. The individual would not be penalized unduly if he attended a small high school which did not give all courses required by the college. He would be able to make up such requirements by taking extra work in college or by individual study. Further advantage would be that it would not be necessary to take the preliminary college preparation in the institution in which he intended to take his degree. Such preparation could be made in any 4-year college or any junior college. The junior college would prepare students for a specific examination to be taken in competition with students from other schools. Another advantage to the student would be that those not suited to pursue an engineering career would be eliminated at the start of their college career rather than later. A student so eliminated would not have the stigma of being dropped from college or out of a curriculum merely because he guessed incorrectly as to his aptitudes, nor would he waste the time usually needed to fail. Increasing the level of preparation would leave additional time in the final three years for more humanistic or technical subjects. A further advantage to students with adequate high-school training is that it would be possible to graduate in four years.

Perhaps the proposed entrance examinations could be integrated with the "sophomore achievement examinations" proposed by the committee on student selection and guidance in the 14th annual report of the Engineers' Council for Professional Development. The intent of both examinations is the same—to measure the student's preparation in the fundamentals of engineering before he goes too far with his professional studies.

The engineering profession would have to become more interested in the process of testing and would have to work with psychologists in making any plan of testing satisfactory. This would not be an inexpensive program, but the benefit to be obtained in increased efficiency in teaching a carefully screened or prepared group would outweigh by far the expense involved.

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The ideas in this article comprise another possible solution to a problem which is vital to the entire engineering profession. The suggestions are those of the authors and do not necessarily represent the opinions of the Iowa State College.

Engineering Teaching Inducements

Engineering instruction offers many inducements as a professional career according to Doctor R. M. Brick, director of the metallurgical engineering department of the University of Pittsburgh, Pa. In the June issue of *Mining and Metallurgy* he cites the need for more qualified men with engineering training to go into the teaching profession.

Among the inducements offered are social and professional prestige, freedom to express and receive full credit for ideas, security from sudden economic whirlwinds, good vacations and general working hours, a fine environment, association with stimulating thinkers, and excellent educational opportunities for both self and family.

Opposing factors to teaching engineering are low salaries, inadequate and obsolete research and instructional facilities, and the stepchild-status of the engineer in a university. However, all of the factors are not capable of monetary evaluation. Regarding salaries, most universities pay $2,100 to $2,500 to new instructors for a ten month period, but government- or industry-sponsored research often offers the faculty member an opportunity to increase his income.

D-C Power for the Chlorine-Caustic Industry

M. S. KIRCHER D. O. HUBBARD

The second largest consumption of d-c power in the United States for electrochemical use is by the chlorine-caustic industry which is expected to have a capacity of about 494,000 kw before the end of this year. Two major types of electrolytic cells—the diaphragm type and the mercury cathode type—are used to produce chlorine and either potassium or sodium hydroxide. Since 1936 most of the conversion equipment installed for supplying these cells has been mercury-arc rectifiers.

CHLORINE–CAUSTIC production is one of the electrochemical industries in which an element or a compound is produced in an electrolytic cell where the current passed actually enters into the chemical reaction produced. The major electrochemical industries in the United States at the peak of the war period were: aluminum, magnesium, chlorine, zinc, and copper, listed in the order of their consumption of direct current for electrolysis. The aluminum industry was well in the lead with a direct current consumption of about 1,840,000 kw, while magnesium and chlorine were relatively close together with about 500,000 kw and 450,000 kw respectively. Since the war aluminum production has been cut back somewhat and magnesium production has been cut back very radically, while chlorine production has increased and may reach a peak of about 494,000 kw before the end of this year to make it the second largest electrochemical industry in the United States.

The chlorine industry in the United States is composed of a relatively small number of large plants and a large number of small plants. Of the 60-odd plants, 20 of them have a capacity of 100 tons of chlorine per day or more and a capacity of about 82 per cent of the total United States production capacity. A majority of these plants are captive with all of their chlorine being used by the owner for the production of other chemicals. A large number of the plants operate as partly captive plants with the excess above captive requirements being sold, and a relatively small number of the plants sell all of their production. The general trend for increased production is to expand the capacity of present plants and to build a few new plants of fairly large capacity. Indications are that plants will be operating near their maximum capacity and that those plants may fall behind the demands.

Essential substance of a conference paper, "Power Conversion for the Chlorine Caustic Industry," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

M. S. Kircher and **D. O. Hubbard** are with the Hooker Electrochemical Company Niagara Falls, N. Y.

LOCATION

The geographic locations of the chlorine plants and their relative capacity emphasizes the economic factors in the production of chlorine and caustic. Electric power is generally the largest single cost item. The cost of salt may be an appreciable item. For profitable operation in a highly competitive industry these two items must be kept at a minimum. Obviously brine from salt wells on or near the plant property is much less expensive than mined salt shipped by rail. One major salt area where power can be generated at a low figure extends through parts of Michigan, Ohio, West Virginia, and western Pennsylvania. Another such area is in Texas and Louisiana. It is to be noted that these areas also produce the major portion of the chlorine in the United States. The importance of the price of electric power is shown by the early development of a large production at Niagara Falls where power was cheap but salt had to be shipped in by rail. The large number of small plants which are located at a distance from salt deposits are generally captive plants wherein the entire production or the major portion of the production is used to supply chlorine or caustic or both to plant processes already in operation at those plants.

A chlorine-caustic plant consists of several departments, namely: brine preparation, power conversion, electrolytic, chlorine handling, and caustic handling. While all five departments are important, the only ones of interest so far as this article is concerned are the power conversion and the electrolytic. Before power conversion equipment can be investigated, a knowledge of the cells and their operating characteristics is essential. There are in use today two main classes of chlorine-caustic cells, the diaphragm cell and the mercury cathode cell.

DIAPHRAGM CELL

The diaphragm cell (Figure 1), a schematic sketch of which is shown in Figure 2, as its name implies depends upon a diaphragm for proper operation. This

diaphragm keeps the chlorine, produced at the anode, from mixing with sodium hydroxide and the hydrogen which are produced at the cathode. Brine is fed continuously into the anode compartment from which it flows through the diaphragm into the cathode compartment and hence out of the cell through a discharge pipe. A total electrical analysis of a cell can be rather complicated, but from the power conversion standpoint it can be simplified to its three major categories which are: decomposition voltage, electrode overvoltages, and straight resistance voltage drop through the electric circuit in the cell. The decomposition voltage is the potential that must be impressed on the cell before appreciable current will flow or any work will be done in the cell. It is also the voltage output or back electromotive force of the cell when the impressed current is removed. The electrode overvoltages are a function of the current density at the electrodes. They can be measured but not calculated. The balance of the voltage drop in the cell follows Ohm's Law, but because of the number of parts and balance in parallel circuits it is simpler to work from plotted voltage–current curves from actual measurements than to calculate the voltage drop.

From the standpoint of the power conversion equipment on diaphragm cells the first 2.3 volts per cell, the decomposition voltage, is reached without the use of power and above that point the conditions are very similar to a straight variable resistance load. The change in resistance is a function of cell life and condition. As the cell life increases, wear at the graphite anode and deposits on the diaphragm gradually increase the electrical resistance through the cell. A new Hooker-type *S* cell started at its rated current of 7,500 amperes would have a voltage drop of about 3.2 volts and at the end of its life would have a voltage drop of about 4.2–4.3 volts and have an average voltage of about 3.4 volts for its life. When the current on the cell changes, the portion above 2.3 volts follows Ohm's Law approximately, although, where accuracy is desired actual plots of the voltage-current relationship should be used.

MERCURY CATHODE CELL

In the mercury cathode cell (Figure 3), a schematic sketch of which is shown in Figure 4, the operation is based on the deposition of elemental sodium rather than hydrogen at the mercury cathode because of the high hydrogen overvoltage at the mercury cathode, and upon the solubility of sodium in mercury. A saturated brine is fed into one end of the cell and discharged at the other end of the cell. During its passage between the electrodes, chlorine is liberated at the anode and sodium at the mercury cathode where the sodium dissolves in the mercury. The resultant sodium amalgam leaves the electrolyzer at the low end where it flows through a decomposer counter current to water. The sodium from the amalgam, in the presence of graphite, reacts with the water to form sodium hydroxide and hydrogen. At the low end of the decomposer the mercury is pumped to the high end of the electrolyzer to start through the cycle again. In the mercury cathode cell the decomposition voltage is about 3.07 volts and the other voltage drops increase the total to about 4 volts with an end life voltage of 4.5–5.5 volts. The total voltage and end voltage for the mercury cathode cells seem to vary considerably from one installation to another. From the standpoint of the power supply the action with the mercury cell is the same as with the diaphragm cell except for a difference in voltage.

Approximately 28 types of cells, mostly of the diaphragm class, have been used commercially for the production of chlorine and caustic in the United States. Of these, 23 types of cells are known that are still in operation, some at about 1,000 amperes, some at 20,000 amperes, and others at various currents between these extremes. Cells of approximately 1,000 amperes rated capacity were very popular and a large number were

Figure 1. Hooker-type S electrolytic cell with anode, cathode, and diaphragm in place but with top removed

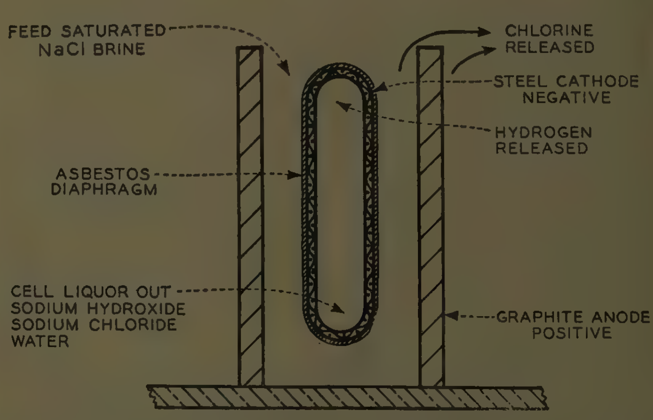

Figure 2. Schematic diagram of diaphragm-type electrolytic cell

developed. Of the 18 types of cells in the 1,000–7,000-ampere capacity, the total installed production capacity is about 1,550 tons of chlorine per day. Most of those small cells now are considered obsolete and only two or three of them are considered for expansion or new installations. Because the cells rated at currents between 7,000 and 16,000 amperes generally were considered to be the most economical to install and operate during the largest expansion period of the chlorine industry, most of the new plants used the high current cells. Thus, a major portion of the chlorine (3,090 tons) is being produced in four types of cells in that range. The one type in the 16,000–20,000-ampere size is a recently developed cell for large plants and its place in the field will be governed largely by future economic conditions.

The production capacity of a cell is directly proportional to the cell current after a slight correction has been made for current efficiency. Thus the largest cells have a capacity of 20 times the smallest cells and for a given installation would require $^{1}/_{20}$ as many cells.

CELL SELECTION

There are a number of factors that govern the selection of cells for a given plant, but usually economics is the deciding factor. The economic evaluation includes the caustic evaporation and power conversion equipment as well as the cells. For example, a large high-current cell has a lower investment cost and lower operating cost than the number of small cells required for the same production. However, in a small plant, the few high-current cells required for the production result in a high-current low-voltage circuit. This may force the selection of lower voltage conversion equipment with a lower efficiency. For example, a plant that required 100 20,000-ampere cells would have a circuit of about 350 volts, but with 10,000-ampere cells 200 would be required and, if placed in one circuit, would require 700 volts. With the smaller cells mercury-arc rectifiers probably would be selected with a conversion efficiency of about 95–96 per cent. For the large cells, however, mercury-arc rectifiers or rotary converters could be used with a conversion efficiency of only about 92 per cent. If the plant were to be only half as large the voltages would be 175 and 350, respectively. The large cells probably would have to use motor generator sets at a rather low conversion efficiency while the smaller cells could use rotary converters or mercury-arc rectifiers with a conversion efficiency of about 92 per cent. If 5,000-ampere cells were considered in one circuit, the voltage would be 700 and the power conversion efficiency about 96 per cent with mercury-arc rectifiers. As the size of the cell decreases, the investment for cells and installations increase, larger buildings are required which increase the cost, and more labor is required for renewal and routine inspection. But as the circuit voltage decreases, less efficient conversion equipment must be used. Thus, for a given plant, an economic study is required to balance the investment cost against power cost at various conversion efficiencies where high conversion efficiencies can be obtained only by using a lower current more expensive cell installation.

In the afore-mentioned comparison, current ratings were assumed in even multiples for convenience, but in actual practice the choice is not so easy. Cells in common commercial use today are rated approximately at 1,000, 2,000, 7,500, 12,000, and 20,000 amperes. While most cells can be operated over a rather wide current range the power required per ton of production is a function of current which introduces another variable in the economic evaluation of cells and power conversion equipment.

It is interesting to note that since 1936 the chlorine industry has been more than doubled and that all but a very small portion of this increased production is using mercury-arc rectifiers for the power conversion. The rapid growth in that period, and to some extent the very extensive use of mercury-arc rectifiers, can be attributed to war conditions which required an extensive increase in production at a relatively few large plants and made the procurement of the rotary type of conversion equipment more difficult.

Figure 3. Modern vertical mercury-cathode-type electrolytic cell of German design

The major types of power conversion equipment available for heavy duty d-c circuits are: the motor generator set, rotary converter, mercury-arc rectifier, and mechanical or contact rectifier. The mechanical rectifier has a high efficiency, low weight, and small space requirement. It has been used in several German chlorine plants and is being introduced in the United States by an American manufacturer.

In the comparison of various types of conversion equipment there are a large number of points that should be considered. For a chlorine-caustic plant some of these points are minor, or the conditions of a particular

plant may eliminate some of them. From the standpoint of the chlorine industry there are five main points to be considered in the selection of conversion equipment, namely:

1. Reliability of operation.
2. Flexibility of voltage control.
3. High conversion efficiency at 200–300 volts, and possibly lower voltages.
4. Resistance to corrosive atmospheres.
5. Cost of equipment installed and maintenance costs.

RELIABLE OPERATION

Frequently chlorine plants are operated to produce chlorine for direct use in another process where it is more economical to operate at a rate suitable to the major process than to provide chlorine liquefaction and liquid chlorine storage. Chlorine is a gas at normal temperatures and requires 150–250 pounds per square inch working pressure storage tanks. Under these conditions interruptions caused by the conversion equipment not only interrupt the production, but may result in spoiled product or expensive steps to get back to uniform production. Even when the chlorine is liquefied a power failure upsets the balance in the cell, reducing efficiency for a period so that the costs are actually in excess of the production loss for the down period.

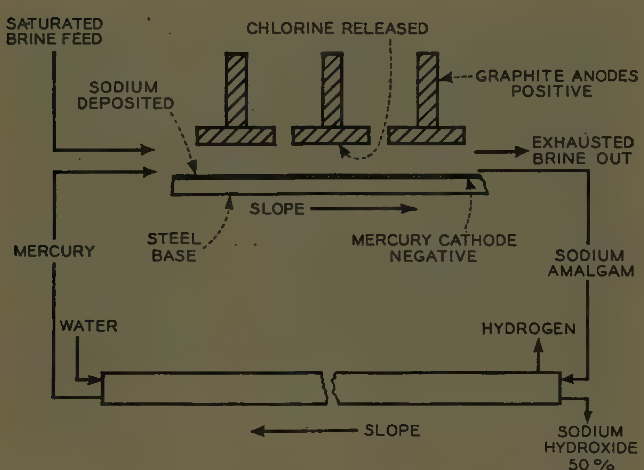

Figure 4. Schematic diagram of mercury-cathode-type electrolytic cell

FLEXIBLE VOLTAGE CONTROL

Conversion equipment is adjusted to a voltage which results in the desired current flowing through the cells. Where the chlorine production is used directly in another process it is frequently necessary to be able to change the chlorine production rate to conform to the requirements of the associated process. Even where there is no tie-in with another process, it is frequently desirable to be able to change the current over a range of 50 per cent of maximum to maximum current.

HIGH CONVERSION EFFICIENCY

For all of the conversion equipment in use in the United States today the conversion efficiency drops off as the current is reduced and drops as the machine load is reduced from a point near its rated capacity. As discussed earlier, the conversion efficiency is an essential item to the economics of chlorine production and can, to some extent, influence the size of cell to be used. One type of conversion equipment, the mechanical rectifier, promises to provide a high conversion efficiency at low voltages and at reduced loads. To date the mechanical rectifiers have been used only in Germany.

Low-voltage circuits are also desirable from the standpoint of safety. A chlorine cell circuit has four or more current leakage lines from each cell to ground. The actual leakage through these paths to ground is negligible as long as a positive ground is not established. Therefore, the electrical center of the circuit is at ground potential while one end is one-half of the circuit voltage above ground potential and the other end of the circuit as much the other side of ground potential. Actually the electrical center of the circuit may shift several cells from the actual center of the circuit. A ground at one end of the circuit would place the other end of the circuit at full circuit voltage as the potential difference to ground. With the Hooker-type *S* cells individual cells are short-circuited out and then removed from the circuit instead of having one standby circuit that can be shut down for renewal without reducing the production. When operating that way the cell renewal men are handling live bus bar with a high potential difference to ground. With a long circuit, say 700 volts, each end of the cell circuit may be 300 to 400 volts from ground potential. An accident near the other end of the circuit may increase this figure to nearly 700 volts. While safety equipment is used and all precautions are taken, such high voltages are a definite hazard and from the standpoint of safety it is preferred to keep the circuits at 350 volts total or lower. It is, therefore, desirable to be able to obtain conversion efficiencies at low voltages for economic and safety reasons.

In view of the afore-mentioned statements, it may seem contradictory that the high tonnage production is in the circuits of 400 volts and higher. However, all of these circuits are operated with mercury-arc rectifiers which have higher efficiency at the higher voltages, and if the high efficiencies were obtainable at lower voltages, shorter circuits would be used for safety.

While the amount of corrosive gas in the atmosphere of a chemical plant may be sufficiently low so that it is not noticeable except during emergencies or breakdowns, it still will be sufficiently high to increase materially the corrosive effect of the air. With motor generator sets and rotary converters there are large commutators

and slip rings that are subject to corrosion. Also, large quantities of air are required for cooling. When air cleaners must be installed the problem becomes a major one. With mercury-arc rectifiers the requirement for air cooling is less and the equipment design is such that the effect of corrosion does less damage. Trouble also may develop with dust deposits across insulated gaps despite periodic cleaning. A design that could eliminate these difficulties would be very desirable as long as it did not result in a material increase in the cost of the machine.

COSTS

In a highly competitive business all costs must be surveyed carefully. Expensive equipment, including its installation cost, contributes to high operating costs just as much as high maintenance costs do. However, there is no real economy in installing low cost equipment if it results in high maintenance costs.

In this article some points have been set forth which are believed important to the improvement in design of power conversion equipment that may be used in future chlorine plants. With the close relationship that is involved between power conversion equipment and electrolytic cells, some idea of the size and design of the cells of the future will be helpful in connection with the design or improvement of future power conversion equipment. It is obvious that the trend in the design of chlorine-caustic cells has been in the direction of larger, higher current units. To some extent the present use of high-current cells is limited by the efficiency of the conversion equipment as discussed earlier. It is reasonable to expect that as high current power conversion equipment with a high efficiency at low voltages is proved practical, high current cells will be used more extensively and cells of 40,000–60,000 amperes and possibly higher undoubtedly will be developed and used as soon as is practical.

D-C Power for Magnesium Plants

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Of primary importance to the magnesium reduction industry is reliability of power supply. Many of the plants built for the production of the vital material had their own power plants which supplied alternating current to conversion equipment. The major part of the conversion capacity was supplied by mercury-arc rectifiers which provided an excellent service record.

EXPANSION of magnesium production facilities for the period of 1930 to 1940 in the United States was very slow and gradual until World War II necessitated a huge expansion to satisfy military needs. In 1933 the total available conversion equipment for d-c power in the magnesium industry was rated 3,000 kw at 100 volts and 30,000 amperes. In 1933 this equipment was operating at approximately 33 volts and 30,000 amperes, or 1,000 kw. In 1934 these facilities were expanded to 6,000 kw; in 1936 to 12,000 kw; and in 1939 to 18,000 kw. In 1941, the first large expansion raised the facilities to a rating of 54,000 kw; in 1942 to 90,000 kw, and in 1943 to a peak of 503,000 kw. Of this total, 76,000 kw consisted of motor generator sets and the remainder of mercury-arc rectifiers. At the close of the war, the production capacity was cut back to practically zero. Operating at this time is one plant with a capacity of 36,000 kw and two other plants are being kept in a standby condition for emergency production, should conditions be such that they require such action.

It is also interesting to note that of the total peak magnesium production capacity of 586,000,000 pounds per year, 424,000,000 pounds, or 73 per cent of this capacity, are located in plants using the electrolytic process. Of the total magnesium produced for the period of 1941 to 1944, 85 per cent was produced in these electrolytic plants. The remainder was supplied by the ferrosilicon and the carbothermic processes. The figures for capacity given do not include conversion equipment required for make-up chlorine which was necessary in some of these plants.

Successful electrolytic production of magnesium sets

Essential substance of conference paper, "D-C Power for Magnesium" presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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Figure 1. Close banking and protection against the highly contaminated magnesium plant atmosphere was possible with these 15-kv bronze-armored cables with a capacity of 168,000 kva

up definite requirements for its electric system which can be listed in importance as follows:

1. Continuity of d-c power at a high current rate.
2. Adjustability of voltage necessary to start up and shut down cell lines and to regulate load to meet contracted power demand.
3. Low power cost and high conversion efficiency.
4. Low maintenance cost and simplicity of operation.
5. Freedom from harmonics in the supplying system to eliminate generator heating and telephone inductive interference.

In spite of wartime principles to obtain materials to wage successful war at any cost, efficiency of design and operation must be recognized.

CONTINUITY OF POWER

Continuity of power service at a high current rate is listed at the top as a requirement in magnesium production. In all the electrolytic magnesium processes, fused magnesium chloride is the electrolyte which must be kept in a fused state by the passage of electric current through the cell. A reduction of current to approximately 66 per cent of the designed value to a cell line is about the absolute limit for the present-day cells. Below this value the cell is in trouble if run at such a low rate continuously. This limit can be dropped to about 55 per cent of design current rating if held for a period not exceeding 8–10 hours. Complete current shutoff can be tolerated for only one hour. After this, crusting and bridging of the bath between the anode and cathode begins. To insure against complete freezing of the cells, auxiliary heating must be supplied to them. With this auxiliary heat, the cell can be maintained without current for a considerable period. This insurance against current failure requires expensive furnace settings at each cell with one or two sources of fuel supply.

Continuity of power supply is dependent upon the following factors:

1. Primary power source.
2. Method of transmission of primary power.
3. Reliability of conversion equipment.
4. D-c cell bus design.

The plants with their own generating stations have the advantage from the standpoint of primary power reliability. In most cases, these power plants were within a few hundred or a few thousand feet of the cell buildings and the conversion equipment (Figure 1).

This type of power transmission was ideal from the standpoint of reliability with no lightning exposure and no storm outages. The war-built Defense Plant Corporation installations have weathered two or three storms with wind velocities beyond 100 miles per hour.

The plants which obtained power from utilities or other power networks were subjected to the hazard of overhead open line power feeder outages. Feeders vary in length and voltage characteristics from 3 miles to 20 miles and from 120 kv to 230 kv. That also presented an additional hazard of insulator contamination of the main substation in the magnesium plant. This could be overcome partially by locating the high-voltage substation at some distance from the process plants, especially those plants which include hydrochloric acid furnaces and magnesium chloride dryers. A preferred substation layout keeps all 13.8-kv switchgear and equipment indoors.

Figure 2. Rectifier room showing (from left to right) anode circuit breakers, rectifiers, firing control cubicles, cathode circuit breakers, and the positive cell bus

CONVERSION RELIABILITY

The mercury-arc rectifier provided the magnesium industry with the reliability which it required. Operat-

ing records will show availability of approximately 99 per cent so that it has been unnecessary to provide spare capacity. Certain design precautions however should be observed to maintain the reliability desired. These may be classified as follows:

1. Adequate rectifier switchgear and protective equipment, such as relays, temperature indicators, and alarms.

2. Adequate vacuum maintaining and measuring equipment.

3. Adequate source of cooling water for the rectifier and its auxiliaries, and adequate rectifier cooling equipment.

4. Adequate ventilation of rectifier rooms and the control rooms.

5. Adequate design of transformers and interphase units.

In a typical magnesium rectifier layout the power feeders are brought into the power switchgear building by underground cables. Individual feeders to the rectifiers are taken from this switchgear to the phase shifters and then to the rectifier transformers or directly to the rectifier transformers. The anode connections are taken through anode circuit breakers to the rectifier skids which consist of 12 single-anode rectifier tanks, and the cathodes from the rectifier skids are connected to the main positive bus through the cathode circuit breaker. The cell line negative bus is taken directly from the neutral of the rectifier transformer without any interposing switching equipment.

In the rectifier room proper (Figure 2) the anode busses are taken under the floor to the individual rectifier tanks. Rectifier firing control cubicles are located adjacent to the skids. The main rectifier control panel is located in the middle of the building as well as the auxiliary rectifier power control cubicle. Cathode circuit breakers are connected directly to the positive cell bus with a d-c shunt for measurement of direct current in this connection.

A similar rectifier room has the anode circuit breakers omitted and high-speed cathode circuit breakers substituted for the semihigh-speed cathode circuit breakers. The rectifiers in this layout also are supplied with balance coils to balance load on each pair of single anode tanks operating in parallel.

ARC-BACKS

The rectifier unit itself is a reliable piece of equipment subject only to arc-backs that are inherent to it. The arc-back record for one year for 12 units indicated approximately an average of three arc-backs per unit per month for units in service under full load for two years. After the failure of a peaking reactor in the firing circuit of one unit, its record cleared up to where it compared favorably with all the remaining units. While this frequency of arc-backs is a nuisance, it is not considered serious when protective equipment is adequate. However, arc-backs have a serious effect on transformers if they are braced inadequately (Figure 3). It is possible that the addition of anode circuit breakers which would clear arc-backs faster at a lower reverse current value might minimize this defect. It is believed at this time that anode circuit breakers are desirable.

No particular difficulty has been experienced with vacuum sealing and maintaining equipment as presently designed. Periodic maintenance is required to keep the mechanical and the mercury vacuum pumps in good operating condition.

RECTIFIER CONTROL

The main control panel for a 60,000-ampere rectifier installation contains the necessary a-c ammeter, d-c voltmeter and ammeters, vacuum indicators, firing position indicators, annunciator, and a-c and d-c circuit breaker controls. The backs of these panels include overcurrent relaying, ground fault relaying, auxiliary relays, and time meters. Designs of this equipment have been found adequate except with the ground fault relays. High-speed induction-disk-type relays with short time settings replaced the instantaneous type since the instantaneous type often gave false tripping on excitation inrush or arc-back. It has been advantageous to use synthetic insulated control cables for connecting these controls since they are resistant to chemical contamination such as is found in these plants.

RECTIFIER TRANSFORMERS

The rectifier transformers usually are located just outside of the rectifier room wall. The anode cables

Figure 3. Serious distortion of rectifier transformer secondary as a result of inadequate bracing to withstand results of arc-back

thus are kept as short as possible. These cables should be braced adequately to remove any strain from the rectifier transformer bushings and the rectifier bus supporting insulators. The connections to the negative cell bus are made directly without interposed switching, and the primary cables are brought to the units underground. Electrolysis of cables was prevented by covering the lead sheath with a bituminous impregnated or a rubber jacket. Overhead cables are recommended for future installations, allowing more efficient use of the copper and providing no electrolysis problem.

RECTIFIER COOLING

The cooling water to rectifier units is as important for reliability of operation as is the primary power source. Two sources of water should be provided if possible, one for regular and one for the emergency supply. Two separate headers for each source allow transfer of heat exchangers separately for each unit without shutdown of the complete station. Replaceable nipples are provided where taps are taken from the headers. This allows for maintenance without interruption of water supply. A 4-way valve system always should be provided for throwing each header on either source of water supply. This precaution has saved plant shutdowns since operators are able to throw over the cooling system to the emergency supply when alarm equipment indicated water source failure. Care also must be used in the selection of heat exchangers, tubing, and piping so that they are satisfactory for local water conditions. Complete spare heat exchanger assemblies should be available for replacements, so that the heat exchangers may be retubed in the maintenance shop without delay in rectifier output.

RECTIFIER ROOM VENTILATION

Rectifier rooms should be ventilated adequately with a clean washed and cool supply of air. Failure to furnish clean air results in control cubicle wiring breakdown, breakdown in copper-oxide rectifiers used in the firing circuit, and failure of relay coils and contacts. It is advantageous to wire all control cubicles with synthetic insulation of at least 1,000 volts rating where ambient temperature permits. Glass and silicone insulation would be advantageous for high temperature locations. A simplification of firing control equipment is desirable to eliminate maintenance which present designs require. Failures of ordinary types of switchboard wiring now used in units are quite frequent where ventilating equipment is inadequate.

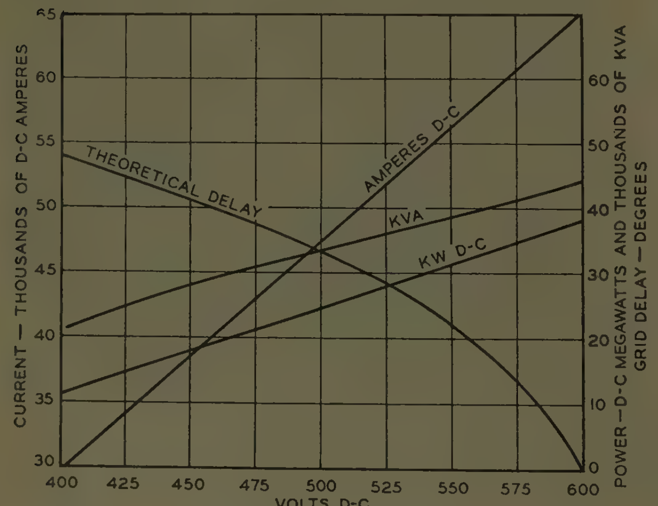

Figure 4. Load ratio curves for magnesium cell rectifier

VOLTAGE AND CURRENT CONTROL

Since a magnesium cell line consists of a number of cells in series, it is not possible to start all of these ce'ls in the circuit at one time. The conversion equipment is called on for full current output at reduced voltage. A typical starting schedule for a magnesium cell line requires autotransformer and rectifier transformer tap settings at the lowest point. In addition, reduction is required by rectifier firing delay to bring rectifier output voltage to approvimately 30 per cent of rating. The addition of more cells after several days may require the same tap settings but a reduction in firing delay to increase the voltage. Further addition of cells would require a change in the autotransformer and the rectifier transformer tap settings. Since the tap setting operations are spaced several days apart, manually operated tap changers are satisfactory. These changes require a shutdown of rectifiers which are energized from the same autotransformer while the other units continue on the bus. Where conditions do not change rapidly in the cell circuit, manual tap changers for adjustment of voltage are satisfactory.

It should be noted here that 15 per cent is the usual limit for continuous voltage adjustment by firing delay. This is limited by the design of the interphase transformers, however, in one case as much as 37 per cent reduction was required for a period of seven days. The temperature of the interphase transformers and of the rectifier transformers was observed by thermocouples located at appropriate points in both units. These did not exceed allowable limits for this type of equipment, being actually 50 to 60 degrees centigrade total temperature.

For shutting down of a cell line, no changing of taps of the autotransformer is required. It is necessary only to advance the firing delay to such a point that a rectifier output voltage equals that of the cell back electromotive force.

The current output of a mercury-arc rectifier varies with the voltage applied to the terminals of the rectifier transformer (Figure 4). The regulation of any transmission line feeding rectifiers will affect the rectifier current output to any cell line with a constant number of cells, therefore, to maintain the kilovolt-ampere

power demand at any contracted limit, it becomes necessary to regulate the voltage to this d-c load. This can be done in one of two ways, by tap-changing-under-load transformers, or by adjusting rectifier firing control. Since rotating equipment such as motors will operate satisfactorily with 10 per cent variation, tap-changing-under-load transformers for rectifiers serving magnesium cell loads are not required if line regulation does not exceed 10 per cent. Adjustment for this regulation by firing control results in approximate reduction of 1.5 per cent in current and production. However demand or production in some cases may dictate that 1.5 per cent loss in production be retrieved, and this condition then would dictate tap-changing-under-load transformers, which was the case in the early part of World War II.

During the period while electrodes are being adjusted in the cells, the cell series may require from 5 to $7^1/_2$ per cent increase in voltage. The firing control is satisfactory for taking care of this condition. Care must be taken that the manual taps are set to give sufficient range to reach the maximum voltage required.

Where wider swings in total current output are required, which may be the case when steam conditions or generating conditions are unstable at the power supply system, tap changing under load is mandatory. Automatic control of tap changers is not generally considered necessary. If voltage swings are frequent, this may require excessive operation of the tap changing mechanisms. Where a 15-minute interval establishes the demand for the month, it is suggested than an integrating control be used. Thus the tap changers would be allowed to stand idle for the first five minutes of this interval. The integrating device would set the taps for a definite demand for the next five minutes and at the expiration of the second five minute period set the taps for the final five minute period so as to maintain the demand for the total 15-minute period under the predetermined value. This type of automatic control would be similar to tie line load frequency controls except that flat tie line demand would not be maintained continuously except for five minute intervals to totalize contracted demand for 15 minutes.

CONVERSION EFFICIENCY

The tendency of the magnesium industry to go to voltages 600 volts and above for cell circuits has put mercury-arc rectifiers in a favorable position from the efficiency standpoint. At 600 volts the single-anode type of rectifier has an over-all efficiency of 95.5 per cent including autotransformers and all auxiliaries. This compares with 94.4 per cent for the first multianode type of rectifier, 93.3 per cent for the rotary converter, and 90.3 per cent for the motor generator set. Increasing the rectifier voltage to 780 volts increases the conversion efficiency to approximately 96.5 per cent. Potentials of 1,000 to 1,500 volts now are being considered practical as improvements in cell plant design are made. Recent reports on the contact converter designed and used in Europe during the war show some promise of increasing conversion efficiency still further. While this is still in an early development stage in the United States, the reported 97 to 98 per cent efficiency of this unit at 600 volts looks attractive. In addition simplification of equipment due to the elimination of vacuum pumps, heat exchangers, control valves, and related apparatus should result in a lower capital investment, lower overhead, and lower maintenance cost.

To prove and to measure rectifier conversion efficiency, a higher degree of accuracy is needed in metering the a-c and d-c sides. Commercial accuracy of plus or minus one to two per cent is not satisfactory. Another method of measuring and integrating direct current now is being developed which shows promise of accuracies of 0.25 to 0.50 per cent. Additional information is required on the effect of harmonics on a-c watt-hour meters and indicating instruments, so that correct factors may be used when applying these measurements.

The cost of production for a typical sea water magnesium plant shows power rectification as three per cent of the total cost including depreciation, capital investment, operation, and maintenance. Maintenance routine has been developed to the point where only four hours are required to replace six tanks on a rectifier skid by two men and a foreman. Rectifier tanks are overhauled or repaired on a conditioning rectifying unit for service and replaced when required. Oil circuit breakers are maintained also in advance of their need. Spare vacuum pumps are available in working order for replacement so as not to cause any delay in production. A heat exchanger completely piped, ready for service, always is maintained for duty should leaks develop in any unit in service. It is recommended that the conditioning unit be furnished with a full sized exchanger for this purpose.

HARMONICS

Since mercury-arc rectifiers for magnesium service are usually paralleled on the bus in groups of six, this permits a phase shift of plus and minus ten degrees to give an over-all 36-phase system. No particular difficulty has been reported or experienced with telephone interference. No harmonic filter equipment has been necessary on the d-c side of these units. Plants having up to 75 per cent of rectifier load on powerhouse generating equipment have shown no noticeable generator rotor heating. Inspection of slot wedges in rotors in this service for five years showed absolutely no effects of heating.

Power for magnesium production has shown a phenomenal growth. Due to cutbacks in magnesium production at the end of World War II, some of the

Defense Plant Corporation installations were declared a surplus. Two of the eight plants are being held in reserve for production of magnesium within 90 days and one plant is now in production. Three plants are being dismantled and the conversion equipment disposed of for chlorine production and other electrolytic applications. Another plant is being converted to chlorine production at its present location, and the one remaining plant has been deactivated permanently. With the most efficient plants now operated or being held in reserve, there is nucleus for further production and expansion when required.

Conversion Equipment in the United States Aluminum Industry

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There are a number of advantages in the operation and maintenance of mercury-arc rectifiers in comparison with rotary converters. Operation of rectifiers has been found to be simple, dependable, and relatively free from trouble by the aluminum industry in the United States. Comments and discussion presented apply only to reduction plants of the Aluminum Company of America.

EARLIER installations of conversion equipment by the Aluminum Company of America, Pittsburgh, Pa., were made with rotary converters, and a large part of these installations still are giving satisfactory service. All large installations of conversion equipment since about 1936 have been with mercury-arc rectifiers. Relatively few motor generator sets have been used.

The Aluminum Company of America designed, built, and operated eight reduction plants for the United States Government during World War II. However, any observations concerning equipment in these plants apply only to the period between the time when they were built in 1941 to 1943, and the latter part of 1945, when agreement for the operation of these plants was terminated by the Government.

From an operating point of view some of these advantages of rectifiers over rotary converters are

1. Higher efficiencies in the voltage range used.
2. Considerably less maintenance required, both on the major equipment and on switching equipment.
3. Possibility of switching large cell line loads without the use of a large cell line circuit breaker.
4. Simplicity of operating controls, with fewer possibilities of operating errors.
5. Less susceptible to interruption because of disturbances on the power supply system.
6. Can be placed in service after an interruption more quickly and easily.
7. Lower noise level in operating building.
8. Cleaner and more comfortable working conditions for operators.
9. No relatively large recurring operating expenses as for brushes

ROTARY CONVERTERS

With few exceptions, rotary converters are rated for outputs of 2,500 kw, 5,000 amperes, and 500 volts of direct current, for 6-phase operation at 60 cycles. All rotary converters of this rating are equipped with interpole, as well as shunt field, windings, without synchronous "boosters." At one installation the operating speed is 360 rpm while at another it is 400 rpm. D-c starting normally is used.

OPERATION OF ROTARY CONVERTERS

Under present-day conditions there are no outstanding operating problems with rotary converters. In the

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Essentially full text of a conference paper, "Some Phases of Operation and Maintenance of Conversion Equipment in the Aluminum Industry in the United States," presented at the AIEE summer general meeting in Montreal, Quebec, Canada, June 9–13, 1947.

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earlier days of the installations, "flashovers" occurred frequently because the rotary converter load usually was supplied over transmission lines from more or less isolated power stations with few, if any, system interconnections. Transmission line protective relays were relatively slow, and system speed and voltage regulations were poorer than at present. Many system disturbances occurred and these frequently resulted in "flashovers," with interruption to load and often with damage to the "flashed" converters. With modern high-speed protective relaying, larger and more complete transmission system interconnections, and improved system operating techniques, flashovers due to power supply disturbances are infrequent.

It has been observed that rotary converters appear to be much more susceptible to flashover because of sudden frequency or phase angle changes than because of voltage dips. Severe single-phase faults have occurred on transmission lines connected to a bus supplying a large rotary converter load, resulting in a pronounced voltage dip, but as such faults have been cleared by high-speed relays and as there was no noticeable frequency change because several lines fed the rotary converter bus, no flashover resulted. Flashovers have occurred when a system supplying rotary load has been paralleled with an adjacent large system when the phase-angle between the two systems, at the instant the paralleling switch was closed, did not match closely enough, even though voltages and frequencies agreed closely.

Flashovers still occur occasionally due to sudden change of load on a group of rotary converters. As an example, when the d-c load on a large group of rotary converters on the same bus is dropped suddenly, occasionally one rotary in the group will flash over. This probably is caused by the sudden change in armature phase angle required by the load change and by slight differences in voltage regulation and impedance of individual converters and transformers, resulting in a tendency for one or more rotaries to be "inverted" by others at no load. The inductive voltage rise resulting from the interruption of the heavy d-c circuit may have some effect.

A standard converter without synchronous booster has an essentially constant ratio of alternating to direct voltage. However, by varying the field current, a rotary converter may be caused either to produce or absorb reactive kilovolt-amperes, within certain limits, in the same way as a synchronous motor. The flow of this reactive kilovolt-amperes through the converter transformer and circuit can be used to change somewhat the alternating voltage supplied to the rotary, and hence change the direct voltage slightly, with a maximum variation of 4–5 per cent. Greater variations in voltage are taken care of by changing transformer taps. In a typical case, five per cent taps are provided.

An attempt always is made to operate rotary converters with power factors as high as possible to maintain efficiencies, because rotary converter losses increase rapidly with drop in power factor. In addition, it always is desired to operate converters with at least normal excitation, or possibly even slightly overexcited, to make the operation as stable as possible.

No objectionable difficulties have occurred in the operation of rotaries in parallel with other rotaries in a group, or with other types of equipment. For one older installation the low-voltage leads between the converter transformers and the converters were arranged intentionally with rather large separation to provide relatively high reactance, and the transformers were designed for fairly high reactance. The converters in this installation have been operated successfully for long periods in parallel with rectifiers and with shunt wound d-c generators which have been either parts of motor generator sets or had been driven by hydraulic turbines.

In some more recent installations the low-voltage leads have been shorter and more closely spaced, and the transformers have had a somewhat lower reactance, so that the reactance of the combination has been lower than for the older units, and these newer units do not operate in parallel with each other or with other equipment quite as well as the older converters but such parallel operations nevertheless have been successful.

BRUSHES

In one typical installation of 2,500-kw converters each one has 280 d-c brushes. The commutator speed is about 5,200 feet per minute, and the current density at rated loads is about 46 amperes per square inch of brush. Electrographitic brushes of an intermediate grade are used, and the average useful life per d-c brush is roughly 11,000 hours of converter operation. The commutation is excellent, and the rate of commutator wear is quite satisfactory. Except for occasional damage to commutators due to flashovers, very little commutator maintenance is necessary.

The six a-c collector rings on each of these converters are of brass and operate at a speed of about 4,000 feet per minute, with 11 copper-graphite brushes used per ring at a current density of about 120 amperes per square inch of brush. The average useful life per brush is about 9,000 hours of converter operation, and collector ring wear is quite satisfactory. No oscillators are used now on converter shafts, and no grooves have been cut in the collector rings.

Despite efforts to equalize brush tensions on the collector rings carefully, some selective wearing of the brushes is noticed, with some brushes having a shorter life than others. It is possible that some expedient such as cutting spiral grooves in the slip rings might reduce this selective action and increase average brush life somewhat.

It has been recognized that a certain minimum amount of absolute humidity is necessary for proper brush operation and commutation. It is known that at one rotary

converter installation collector ring brushes have failed in a very short time when the outside temperature was considerably below zero degrees Fahrenheit, so that the absolute humidity was very low. Now the practice is followed of discharging small jets of steam into the air in the converter building in cold weather to keep the humidity at a safe value. With this practice, no difficulty is experienced with abnormal brush wear, but unfortunately no accurate figures are available showing summer versus winter brush life, humidity requirements, and other pertinent data for this installation.

MAINTENANCE OF ROTARY CONVERTERS

There have been very few major failures of rotary converters. At one large installation of converters, most of which are about 30 years old and all of which are at least 17 years old, there have been apparently no more than two or three cases of armature or commutator failures, which made it necessary to dismantle the machine involved. As far as can be determined, no field coil failures have occurred except on auxiliary interpole windings supplied originally, all of which have been disconnected and practically all removed.

Each converter normally is shut down for an hour or two about every 10 to 14 days for inspection, removal of dust and dirt with compressed air, replacement of short brushes, checking of insulation resistance, and other details. A visible card file is kept of the number of a-c and d-c brushes replaced and of insulation resistance readings.

The record of insulation resistance readings now is used as a guide for maintenance on the converters. When low readings develop, an attempt is made to locate and correct the trouble, and the entire winding is given a coat of air-drying varnish. Recently most of the trouble with low readings has been traced to aging and defective insulation under the main interpole field winding. This insulation is replaced when found necessary.

When a converter is damaged by flashover, it is sometimes necessary to replace all d-c brushes, as well as repair the brush rigging, repaint the metal work, and revarnish the insulation in the vicinity of the commutator. It is also sometimes necessary to stone the commutator to restore its surface and to undercut the commutator slot mica. In some cases of flashover on a converter operating in parallel with a large group, when the converter in trouble is equipped with old style relatively slow d-c circuit breakers, the magnetic forces due to the heavy direct currents flowing to the flashed converter from others in the group, have bent badly the d-c busses leading to the commutator connections. High-speed d-c circuit breakers would minimize such trouble.

More or less standard practice is followed in testing and maintaining the converter transformers and their oil. Activated alumina is used to maintain the oil in good condition. In one group of 5,000-kva converter transformers about 30 years old, there never has been a winding failure, and when a transformer was untanked for inspection a year or two ago, the core and coils were found to be in excellent condition, with practically no signs of sludge.

RECTIFIERS

The general arrangement of all rectifier installations has been similar. In almost all cases, a-c power has been at 13.2 kv and 60 cycles. The normal arrangement has consisted of groups of rectifier units of about 10,000 amperes d-c capacity, each connected to a common bus, with each unit consisting of two 5,000-ampere rectifiers.

In some installations units of somewhat lower current rating have been used. The normal direct voltage has been about 600 volts or a little higher with the negative d-c busses of adjacent groups of rectifiers normally connected together solidly with provisions to allow the positive busses to be interconnected through circuit breakers of about 12,000-amperes capacity. Each group of rectifier units has been used to supply one cell line.

Installations have been made with multianode rectifiers and with single-anode-per-tank rectifiers of both the ignitron and "excitron" types.

Each rectifier transformer has served two rectifiers with a separate low-voltage winding for each rectifier. All rectifiers have had 12 anodes. In two original installations, the low-voltage windings were connected quadruple-Y, with 12 low-voltage leads plus neutral from each winding, with one lead per anode. No anode circuit breakers were used. On all other installations, the transformer low-voltage windings have been double-Y, with 6 leads plus neutral from each winding. Six-pole high-speed anode circuit breakers have been used, and anode balancing reactors have been used to allow two anodes to operate in parallel on each transformer anode connection.

Each rectifier transformer and its rectifiers operate as a 6-phase unit. By using a combination of Y- and delta-connected high-voltage windings with additional phase shifting transformers, each group of rectifier units is operated as a multiphase installation. The normal arrangement has been to use 36-phase operation, although other arrangements have been used.

Aluminum has been used for practically all a-c and d-c busses and connections except that in some of the plants built early in the war, copper was substituted because the aluminum was needed more for aircraft production. Later silver was used because of the acute shortage of copper, with aluminum still reserved primarily for aircraft. Many of the aluminum connections were welded, while welding was used extensively on many copper connections.

The choice between water-to-water and water-to-air heat exchangers for the cooling of the rectifier tanks has been made with local conditions in mind. A low cost and dependable water supply usually has favored the

water-to-water heat exchangers. In very cold climates, where the expense of maintaining suitable antifreeze solutions in water-to-air systems would be high, and where there is constant danger of damage by freezing if the strength of the antifreeze is not maintained, water-to-air systems are not desirable. The mercury-diffusion high-vacuum pumps have had separate cooling systems. These pumps usually have been cooled directly by raw water, but at one plant a separate enclosed system using a water-to-air heat exchanger was installed.

The normal arrangement for power supply for auxiliary equipment had consisted of separate transformers, for each group of rectifiers, fed from the same 13.8-kv busses as the rectifier transformers, and supplying power to a 440-volt enclosed bus for each group of rectifiers. These 440-volt busses have been fed through air circuit breakers, with tie circuit breakers to allow adjacent bus sections to be connected together, if necessary. Taps to these busses have been made through small circuit breakers for rectifier auxiliaries, lighting, and building auxiliaries.

OPERATION OF RECTIFIERS

The operation of large groups of rectifiers has been very satisfactory, which is a credit to the manufacturers, and is a result of their development work and of co-operation between the users and manufacturers.

It now is agreed rather definitely that arc-backs no longer are a problem in the operation of ignitron rectifiers. It has not been uncommon for a group of 12 such rectifiers to operate for months at a time with no arc-backs. While many of the ignitron installations originally had arc-back rates which were not considered satisfactory, the causes of most of the arc-backs were determined and corrected. The problem of "misfires" is not particularly troublesome, but at some installations there is room for improvement.

With the older installations of multianode rectifiers, individual rectifiers occasionally develop very bad arc-back records, and it is necessary to overhaul them completely to correct the difficulty. Even when one of these rectifiers is dismantled, it is not always possible to determine the cause of the difficulty.

As noted previously, large d-c cell-line circuit breakers are unnecessary to control the cell-line load on rectifiers. The load is dropped when desired by gang tripping of cathode circuit breakers. After an interruption, all circuit breakers, anode and cathode, are closed, and then the rectifiers are loaded by ignition control, with which it is obviously much simpler to restore cell-line loads fed from rectifiers after an interruption than is the case with rotary converters, as in case of a complete a-c interruption, all converters must be started and synchronized before the large cell-line circuit breaker is closed.

While it is theoretically possible to reduce the direct voltage from rectifiers appreciably by retarding the phase angle of the conduction period by grid control or by controlling the instant of ignition on ignitrons, this method of control is not used normally for more than 1–2 per cent reduction. Whenever possible, rectifiers are operated at full advance. The use of phase control reduces efficiency and power factor somewhat, and in some cases has been observed to increase the misfire rate on ignitrons, and also apparently has been the cause of some arc-backs on multianode rectifiers. The rectifier transformers normally are supplied with $2^1/_2$ per cent taps which can be changed readily and some stations are equipped with regulating means such as automatic tap-changing autotransformers or synchronous condensers on the 13.2-kv bus feeding the rectifiers.

There is normally no difficulty in parallel operation of large groups of rectifiers. In normal operation, a slight amount of phase control on a few rectifiers may be necessary to balance the load on rectifiers in a group. Normally, the group of rectifiers on one cell line is operated isolated on the d-c side from other groups, but under some conditions two or more groups are paralleled on both a-c and d-c sides to make spare capacity in one group available for adjacent groups, if needed because of outages for maintenance or other reasons. It might be thought that the operation of several large groups of rectifiers in parallel would increase arc-back currents to be interrupted appreciably, but tests have indicated that paralleling adjacent groups of rectifiers has little effect on the rate of rise of arc-back currents, so that with high-speed anode circuit breakers, this parallel operation has little effect on the maximum arc-back current interrupted.

It has been found that rectifier loads will be sustained through many severe power supply disturbances without interruption. Alternating voltages have been reduced to low values for short intervals and have recovered without interruption. In a few instances it has been observed that a-c operated magnetic contactors used on ignition circuit control have dropped out on momentary system voltage dips, and then immediately picked up again without interruption. Usually, however, these contactors would not drop out or pick up simultaneously, with the result that a portion of the rectifiers momentarily would carry all the load and thus trip off because of overload, thereby leaving the load on other rectifiers, which in turn would be overloaded. Changes in frequency have little or no effect on the operation of rectifiers. In this respect also the chore of operating rectifiers is simpler than that of operating converters.

There have been some interesting operating experiences at two plants where capacitors were installed for power factor correction and voltage boosting. It was very noticeable, under some combinations of load, number of capacitors connected, and power supply system impedance, that the loads on individual rectifier units in a group became very badly unbalanced. In some extreme cases operation was difficult. In such cases,

the capacitors and the remainder of the power system formed a resonant or near-resonant circuit for certain harmonics, the fifth in some cases, and such large harmonic components appeared in the rectifier anode voltages that the phase angle of conduction of some rectifiers was so retarded that the load on these rectifiers was reduced sufficiently to overload other rectifiers in the group. The amount of retardation depended on the relative shift of the fundamental and of the harmonic by the phase shifter and by the rectifier transformer. This unbalance could be aggravated by shutting down one rectifier unit in a group, thus partially spoiling the effect of multiphase operation, and introducing relatively large harmonics in the supply currents. With normal loads and normal power supply system conditions, this type of unbalance was not a problem even with one unit off, but it was observed at two locations before the power supply system connections to the plant were normal.

Another interesting observation was that rectifier arc-backs occurred simultaneously with the switching on of a 15,000-kva block of capacitors. It had been thought that the use of capacitors possibly would increase the arc-back currents to be interrupted, but oscillographic test of arc-back currents with and without the capacitors connected showed that the capacitors apparently had little or no effect on the arc-back currents.

The arrangements for power supply for auxiliaries has not been altogether satisfactory, although duplicate sources of power for the low-voltage auxiliary busses have been furnished. Interruptions on an entire group of rectifiers have occurred because of the failure of supply to the auxiliary bus or trouble on this bus or connected equipment. For maximum reliability, the essential auxiliaries for each rectifier should be supplied from its own rectifier transformer, making each unit independent for this essential auxiliary power.

The safety of personnel is important in rectifier operation. Many parts of the rectifiers operate at a voltage above ground and the voltage between anodes may be up to about 1,100 volts. Several precautions are taken to prevent accidents.

At several stations, a system of removable ropes or railings has been provided to keep personnel away from energized parts. At some locations, removable plywood shields have been used around the anode studs of ignitrons, so that accidental contact with these studs would be impossible unless these shields were removed. Unauthorized workmen are kept away from the vicinity of the rectifiers.

With a large group of identical rectifiers in a building, care must be used to make certain that a maintenance man works only on a rectifier which has been properly de-energized and tagged for him, rather than to make the mistake of starting on an adjacent energized rectifier which looks exactly the same. The problem is more serious than with a group of rotating machines, as a workman hardly could fail to distinguish between a machine which was rotating and one which was not. Several schemes are possible for clearly identifying the de-energized rectifier. In some locations removable wooden screens have been put in place by the operator to isolate a de-energized rectifier from its neighbors. At other locations, the removable ropes that are used to prevent access to the rectifier have been removed at the de-energized rectifier, and other ropes are placed between this rectifier and adjacent energized rectifiers. At a station using plywood shields over the anode studs, these shields must be removed by the operator and large colored placards placed over the breakers of a de-energized rectifier before a maintenance man can consider the rectifier safe. A system of green lights can be used, with the lights so connected that they will burn only when all operations necessary to clear the rectifier and associated equipment properly have been completed by the operator, and lights plainly would distinguish the cleared rectifier from its energized neighbors.

MAINTENANCE OF RECTIFIERS

Only a moderate amount of routine maintenance has been found necessary on most rectifier equipment. While some of the maintenance has not been as simple as maintaining rotating equipment, there has been no difficulty in training personnel for this work.

There have been no major failures of transformers. Even during the early periods when high arc-back rates were experienced, no transformer failures occurred. The successful operation of high-speed anode circuit breakers protected transformers from damage.

While it originally was feared by some that the maintenance of a high vacuum, with the pumping equipment necessary, would be troublesome, these fears have been shown to have had no justification. The pumping equipment has proved to be rugged and has given little trouble. The various types of vacuum seals used have been quite successful, though some types of gaskets have caused some trouble, as will be mentioned later.

Except for the periodic complete overhauling which seems to be necessary with multianode rectifiers, only a very moderate amount of maintenance is required. At present, it is not known that any periodic opening of ignitron tanks will be necessary. A certain amount of routine inspection and preventive maintenance is done regularly at all plants, on fairly definite schedules. Periodic inspection of vacuum pumping equipment, control and ignition circuit equipment, cooling system equipment, and related apparatus is included.

At most plants, distilled water is used as a coolant, and normally sodium dichromate is used as a rust inhibitor. At one plant, no rust inhibitor is used in the distilled water in one type of rectifier, in which the coolant circulates largely in copper coils. There is no uniform practice for replacing the coolant and rust

inhibitor, but the solution is replaced as leaks occur, or when a rectifier is drained for maintenance.

Very little trouble has occurred with control equipment. It seems that temperature regulating equipment with direct-acting bellows-operated valves may require less maintenance than that which has electric control.

In one type of ignitron rectifier, the life of ignitors now seems to be satisfactory, while in another the life is relatively short, possibly about 18 months. On this latter type, misfires develop after several months operation, so that ignitor adjustments are necessary. A point is finally reached at which the ignitors cannot be adjusted to eliminate misfires, after which the ignitors must be changed. It is usually found that the ignitor tip has become badly eroded.

The inner aluminum wire gaskets originally furnished for the seal of the tank cover and ignitor openings on ignitron rectifiers have been or are being replaced with new gaskets of a synthetic material. The original gaskets were covered with a protective coating of synthetic paint, but wherever this coating became broken the aluminum was attacked by the mercury. In many such instances, the gasket was badly corroded, and the resulting contamination of the mercury frequently caused wetting of the ignitors. This wetting was a deposition of amalgam on the ignitor tips which caused misfires. The use of synthetic gaskets for the inner seals has eliminated this difficulty. The use of the aluminum gaskets for the outer seals, where there is normally no exposure to mercury, has been satisfactory.

In overhauling multianode rectifiers, it always has been thought that extreme cleanliness was necessary in handling the parts to insure correct operation. The experience up to date with ignitron rectifiers apparently has demonstrated that, while reasonable care may be desirable, extreme precautions are not necessary. This thought applies only to the care of the rectifier parts, while all necessary precautions for cleanliness and adequate ventilation, are used to protect maintenance men against the possibility of poisoning by mercury.

The rectifier stations have been equipped with a room for untanking and inspecting rectifiers. These rooms have been provided with forced air ventilation, and normally some means of filtering the air. In some instances, control of humidity has been possible. Floors are painted or covered so that no cracks or openings are left in which mercury could become lodged. A detector to indicate any concentration of mercury vapor in the air has been used. The men have been provided with clean white working clothes, and the value of personal cleanliness, such as frequent washing of hands, has been stressed. As noted previously, these precautions have been thought to be desirable to protect maintenance men, rather than primarily to keep the rectifier parts clean.

Mobile Single-Phase Transformer

A mobile single-phase transformer unit rated 60 cycles, 10,000 kva, 132,000/19,950 volts, has released fixed standby transformer units for other duties, and has added flexibility to the four major transmission substations of the Indianapolis (Ind.) Power and Light Company. This mobile transformer is the product of the General Electric Company.

The unit, largest of its kind in the world, is mounted on a flat-bed carry-all-type trailer. Core and coils are installed in a horizontal position to cut down the over-all height. The equipment is forced-oil cooled.

High-voltage parts have sufficient clearance from the ground to prevent accidental contact, and all moving elements are encased in metal shielding. Power for the auxiliaries is supplied by a control power transformer also mounted on the trailer.

The mobile transformer unit being towed to its destination and (right) the unit connected for operation

Paralleling Rectifiers and Converters

R. J. KENNARD
ASSOCIATE AIEE

The paralleling of mercury-arc rectifiers with rotary converters to increase capacity presents a problem because of the different characteristics of the equipment, but with proper control division of the load can be accomplished successfully.

BUILDING of the electrolytic zinc plant of the Anaconda Copper Mining Company, Great Falls, Mont., in 1916 evoked considerable discussion as to whether the tank direct voltage would be 250 volts, the standard practice at that time, or 500 volts. It was decided that 500 volts would be used with the middle point of the cell line grounded through a circuit breaker and one ohm resistance. After a period of time, this ground connection caused frequent annoyances and at times would open and result in more of a hazard than a safety device. The cell line resistance was only approximately 0.0115 ohm, so the grounding resistance was removed and a ground detector was placed on each cell line with an indicator on the main switchboard and, as soon as a partial or accidental ground appeared, it was removed immediately. The decision to use 500 volts has proved correct both from an operating and economic standpoint, as well as making it possible to parallel rectifiers and rotary converters as later described.

In 1918 a 100,000-cubic-feet-per-minute humidifier was installed in the substation, and when the substation was enlarged in 1925 to its present capacity of nine 5,800-kva rotary converters, a second similar humidifier was installed. These humidifiers were necessary for ventilation, and also for keeping the relative humidity above ten per cent below which point brushes on the converters give considerable trouble.

ZINC PLANT SUBSTATION

Prior to the start of World War II, the zinc plant substation received power at 100,000 volts, which was stepped down through nine 6,100-kva 3-phase 60-cycle oil-insulated water-cooled transformers to 406 volts. This power was supplied to nine 5,800-kva 6-phase synchronous rotary converters, each equipped with its own motor generator booster, which converted the alternating current to 10,000 amperes at 500–580 volts direct current for use in the tank room of the electrolytic plant. One of the nine rotary converters was a spare which could be used on any of the eight tank room circuits. There were several times in the past when the spare converter was paralleled with one or two of the operating rotaries to produce 14,000 amperes per unit instead of 10,500 amperes normally used.

ELECTROLYZING DIVISION

The cell building is 252 by 395 feet in which there are 1,248 cells divided among eight 156-cell units. Each cell contains 32 aluminum cathodes and 33 lead anodes (Figure 1). The cells are in series, in cascades of six or seven cells, and fresh solution may be added to any cell. Zinc sulphate solution, as fed to the cells, contains no free acid, but as the zinc is removed from the solution, sulphuric acid is formed and the solution leaving the cells is low in zinc and high in acid content and is used in the leaching division.

The power to the individual units is proportioned approximately as follows:

1. Decomposition of zinc sulphate—65.79 per cent.
2. Polarization obtained by subtracting the decomposition voltage from the counter electromotive force—11.51 per cent.
3. Conductor bars—3.01 per cent.
4. Electrodes which represent the resistance loss from the tank bar through the plates to the solution level—1.40 per cent.
5. Solution which is affected by the conductivity of the solution and length of path and cross section affected by plate spacing—18.29 per cent.

EXPANSION

At the start of World War II, the demand for zinc increased considerably and it was decided necessary to increase the zinc plant production by 25 per cent as soon as possible. There were three methods for accomplishing this result:

1. A 2-unit plant similar to the present plant except on separate site.
2. A 2-unit addition to the present substation and tank room with remodeling and expansion of the leaching plant, casting division, and other divisions.
3. Paralleling a 3,000-ampere conversion unit with each rotary converter and adding additional plates to each cell of the cell lines to maintain approximately the same current density in the cells. Also remodeling and expansion of the leaching plant, casting division, and other divisions.

The third method would cost less than 50 per cent of either of the other methods. From the experience mentioned previously of paralleling one converter with one or two operating converters, there were enough operating

Essentially full text of a conference paper, "Paralleling Rectifiers and Rotary Converters for the Electrolytic Industry," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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data to prove that this method was perfectly satisfactory as far as the tank room and the leaching operation were concerned. Because of the low percentage of power loss in the conductors, they could be run at the higher current density without serious trouble. First cost, efficiency, dependability, small building requirements, the condition that most manufacturers were swamped with orders for rotating equipment, and minimum of essential materials, made it apparent that rectifiers be considered for paralleling with the converters. It was recognized that this was the first place large synchronous converters would be paralleled with static conversion equipment.

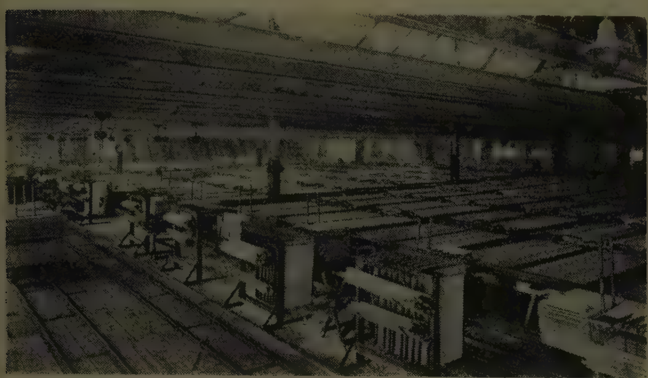

Figure 1. Electrolyzing division of zinc plant

The characteristics of rectifiers are not identical with rotary characteristics, but with the load normally quite constant, it appeared that rectifiers not only would parallel satisfactorily with the converters, but would improve operations materially in the case of line surges which forced converters off the line. The converters when forced off the line because of a severe line surge may take 20 minutes to be replaced in service, and during the storm seasons they may be out of service at frequent intervals. This causes resolution in the tank room which sometimes is quite serious. If rectifiers are paralleled with converters when this condition occurs, the rectifiers can be thrown on the tank circuit immediately thus eliminating resolution entirely. The decision was made to adopt the third method.

PARALLELING

The rectifiers were provided with phase control for obtaining a voltage reduction of 25 per cent. In order to limit their tendency to arc back when subjected to considerable phase retardation, commutating reactors were included in the anode circuits. Because it was desired to operate two rectifiers from one transformer without creating any interference in the operation of two cell lines (Figure 2), anode circuit breakers were used. Thus, in case of an arc-back on one of the two rectifiers the other cell line is not disturbed, except for a temporary increase in the rectifier voltage and the rectifier load, due to the regulation of the transformer.

The installation of the synchronous converters was protected so that in case of flashover on a commutator, the respective d-c and a-c circuit breakers would open. In this particular installation, the flashovers are due mainly to system disturbances. With steady load, the alternating and direct currents in a converter practically are balanced as to the effect of armature reaction, so that the resultant reaction along the axis of the commutating poles is small. Any remaining armature reaction is compensated by the commutating poles which, in addition, create the commutating field necessary for reversal of the armature current.

In case of a disturbance in some part of the power system which results in a sudden rise and a phase advance

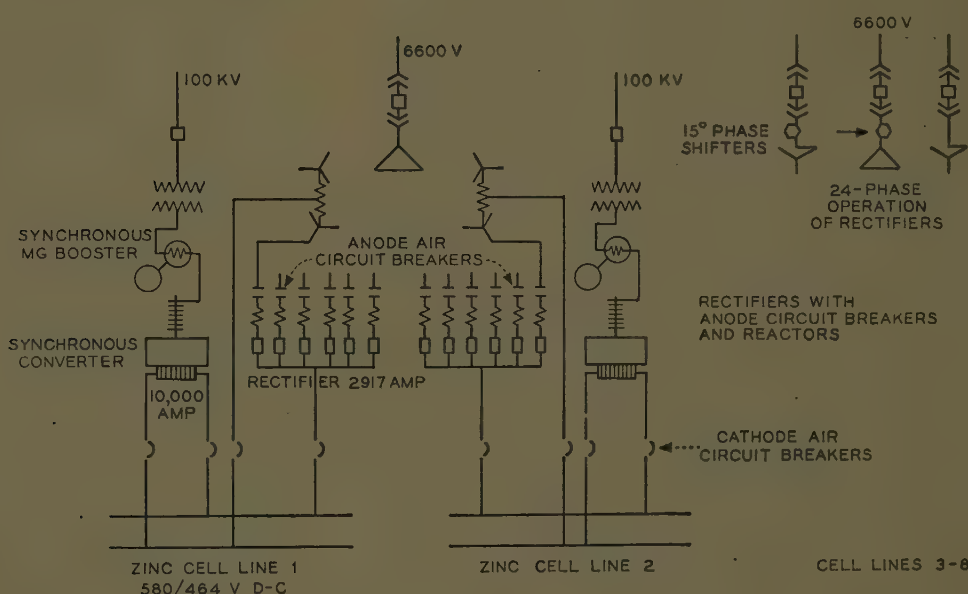

Figure 2. Connections for zinc plant substation with converters and rectifiers in parallel

of the system voltage the alternating current in the converter will increase by the amount of the synchronizing current needed to accelerate the armature into the new synchronous phase position. This synchronizing current produces a relatively strong magnetic field in the commutating zone which increases the voltage induced in the armature coils in this zone possibly to a point where the increased arcing on the commutator will result in what commonly is called a "flashover." This phenomenon is independent of the converter load and even may occur at no load.

The a-c overcurrent relay at the synchronous converter will open the a-c circuit breaker in case of a flashover, while at the same time, the d-c circuit breakers will open on reverse current. In order to eliminate the possibility of the rectifier feeding into the flashover of the synchronous converter, the rectifier cathode circuit breaker is interlocked with the a-c overcurrent relay of the paralleled converter so that the cathode circuit breaker also opens in case of a flashover.

An arc-back on the rectifier trips one or more poles of the anode circuit breaker, and an interlock on this circuit breaker is provided for tripping the cathode circuit breaker immediately thereafter in order to avoid operating the rectifier with only a part of its anodes. This throws the rectifier load on the converter and results in the opening of the d-c circuit breakers of the converter.

Therefore, it is impossible for the converter to feed into an arc-back or the rectifier to feed into a flashover of its parallel converter. It should be noted that the two conversion equipments are actually paralleled at the cell line, which is relatively far removed from the conversion equipments. Therefore, some reactance remains in the circuit between the paralleled converter and rectifier which limits transient currents between the two conversion equipments. Experience during paralleled operation has shown that neither the flashover of the converter nor the arc-back of the rectifier involves any additional hazard for the equipment in view of their parallel operation, although the flashover, if severe enough, may damage the armature of the converter.

CURRENT REGULATORS

An automatic current regulator is provided for each rectifier which not only holds the rectifier current to a constant preset value, but also simplifies the operation during a circuit interruption. An interlock on the cathode circuit breaker forces the regulator into the minimum current (voltage) position when this circuit breaker trips. This position corresponds to about 435 volts (Figure 3) which is just slightly above the counter electromotive force of the cell line. If the regulator is not returned to the low position when the rectifier is reconnected to the cell line, the rectifier temporarily would carry a large overload and its cathode circuit breaker would trip out again.

Automatic action of the regulator permits the operator to throw the rectifier back on the cell line immediately. The regulator then will bring the current up to the rated rectifier capacity, corresponding to about 460 volts, while the operator can confine his attention to the starting of the converter and to adjusting its voltage to the point where rated converter output is obtained. While the converter is being brought up to full load, the voltage of the rectifier is increased steadily by its regulator from 460 to 580 volts, when both equipments in parallel carry full current of about 13,000 amperes.

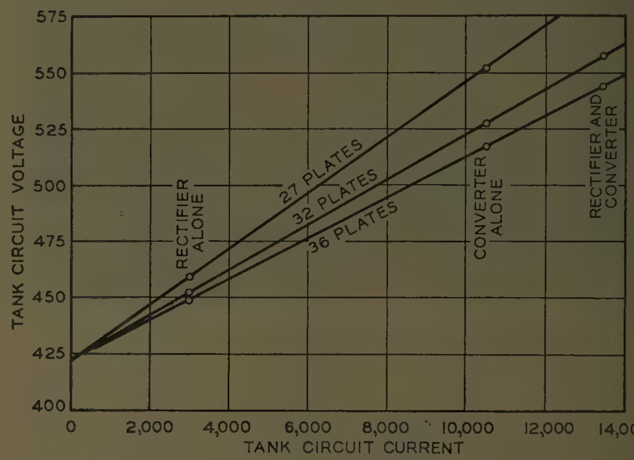

Figure 3. Tank circuit current–voltage characteristics

All interruptions of the current supply to a zinc cell line not only cause a proportional loss of production, but also allow the counter electromotive force of the cells to turn back into solution the zinc deposited on the cathodes, as long as the impressed direct voltage does not exceed the counter electromotive force. The automatic regulation of the rectifier therefore is especially important in this case, because it shortens the time required for reconnecting the d-c supply of the rectifier to the cell line and also for bringing both parallel equipments up to full load.

In the actual practice of the cell-line operation, parallel operation of a rectifier and a synchronous converter has been free from any particular operating problem. This is emphasized because of the often-expressed fear that rotating and static conversion equipments, having somewhat different characteristics, could not be paralleled because they would not share the load in proportion to the rating of the individual equipment. Actually, the division of the load between the two equipments is accomplished quite simply by the proper voltage (current) regulation of each equipment.

The telephone company made a very complete survey of wave analysis and interference to the telephone system from the 24-phase rectifier operation and their tests showed definitely that there was no interference from this source.

Conversion Equipment in the du Pont Company

HAROLD E. HOUCK
MEMBER AIEE

The apparatus for the conversion of a-c to d-c power in various plants of the du Pont Company has included rotary converters, motor generator sets, and mercury-arc rectifiers. Operation and maintenance of this equipment since the company's first converters were installed in 1895 to present rectifier installations has provided much valuable experience and information.

THE largest concentration of conversion equipment in E. I. du Pont de Nemours and Company, Inc., Wilmington, Del., totals about 50,000 kw and is located at the Niagara plant at Niagara Falls, N. Y. This plant was built and operated for many years by the Roessler and Hasslacher Chemical Company which company later became a part of the du Pont Company. Installation of conversion equipment was begun at this plant in 1895 with four synchronous converters which were among the first sizeable machines of their type that were built. They operated on 2,200-volt 2-phase 25-cycle alternating current and their supply transformers were equipped with tap changers to permit adjustment of direct voltage. They were started by direct-connecting induction motors. Within the ensuing 19 years, 12 motor generator sets were installed.

Beginning in 1914, the swing was back to synchronous converters and from 1914 to 1923, nine of them were installed to supplement and later to replace the original converters and the motor generator sets.

About 1930 four larger synchronous converters were installed, each rated at 5,440 kw and having a top voltage of 350 volts and a current rating of 16,000 amperes. A fifth converter of this rating was installed about 1942. These large converters are believed to have the distinction of being the largest ever manufactured, that is, the largest in physical size and in current rating rather than in kilowatt rating.

Long and good service has been obtained from the converters at the Niagara plant. The entire 14 of them continue in daily operation.

Being in electrochemical service, these converters are not required to handle overload currents of the magnitude that are imposed in railway service, for example. It is to be noted, too, that they are in 25-cycle service and, therefore, they are less sensitive and more free from flashover than are 60-cycle rotary converters. It is also true that 25-cycle rotary converters have a conversion efficiency higher than comparable 60-cycle equipment.

In general one large converter and two smaller ones are operated in parallel to supply one cell line. However, various combinations of parallel operation of these machines are possible. With two small converters and one large one operating in parallel, automatic control of cell line current is accomplished by using a controlling ammeter to adjust a motor-operated rheostat in the field of the larger machine.

Several independent loads are supplied from the d-c bus system, and each of the synchronous converters may be connected to either of three or more of the load busses. Thus, many combinations of parallel operation of machines are possible.

This equipment was purchased both new and second-hand over a period of some 30 years. Consequently, there is an assortment of machines of various ratings and with various intermediate voltage ranges. Due to the arrangement of primary transformer taps, there are blank areas in the operating voltage ranges of the several machines. The location and extent of these unavailable voltage areas varies with different combinations of machines operating in parallel. This undesirable feature has limited the flexibility of this installation and has required operation at production rates which are not always optimum schedules. This is true because the production rates of the cell lines are determined by the number of cells operated in series which determines the over-all voltage which must be applied to each cell line. Because of the transformer tap arrangements, it is sometimes necessary to operate above or below the desired voltage and operation at such points may not be at the desired production rate.

The rotary converters are started by energizing them at reduced voltage on the a-c side. The old method of using a field breakup and reversing switch to obtain

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Essential substance of a conference paper, "A-C to D-C Conversion Equipment in the du Pont Company," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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Acknowledgment is made of the opinions and data submitted by G. O. Hayes, Ethyl Corporation, Baton Rouge, La.; and A. M. Hamann (F '34), H. B. Rupert, and F. A. Anderson (M '44) Niagara Falls, N. Y.; L. H. Fletemeyer (M '35) Perth Amboy, N. J.; and W. W. Undy, Pennsgrove, N. J.; all of E. I. du Pont de Nemours and Company, Inc.

Figure 1. Rotary converter enclosed in a special ventilating housing

Figure 2. Twelve-anode ignitron-type mercury-arc rectifier

or change polarity at start-up was never satisfactory and has been abandoned. In its stead, we provided a field flashing system whereby the converter field is excited momentarily at start-up by the 125-volt station control battery. Thus, the correct polarity is established. Manual polarity checking by the operator is preferred to automatic checking.

Inasmuch as various combinations of converters are operated under varying load conditions, it is felt that the total annual conversion efficiency is a more representative index than the efficiency of individual units. For the years 1941 to 1946 inclusive, the over-all conversion efficiency has been between 93.5 and 94 per cent. These figures are the ratio of the total converter d-c power output to the total a-c input measured on the primary side of the supply transformers. This efficiency is obtained with the converters operating in the 300–350-volt d-c range.

Continuity of electric supply for electrolytic loads is of utmost importance. *Planned* overhauls can be executed readily without loss of production, but if conversion equipment is permitted to operate to failure, serious financial losses due to excessive damage to electric equipment, loss of product, or damage to cell equipment will occur. Early experience indicated that a working life of about 14 to 15 years could be expected from the insulation of a rotary converter in Niagara plant service. Subsequently, the practice of reinsulating the slots, coils, and ring studs of all converters after about 13 to 14 years operation was adopted. Midway between these 13- or 14-year periods, the machines are dismantled, thoroughly inspected, cleaned, and repaired where necessary. This scheduling of major maintenance has proved very wise, it is believed. It practically has eliminated premature failures which previously had been destructive and costly. This program includes, also, the reinsulation of all converter transformers at 25-year intervals.

In the location at Niagara Falls, the surrounding atmosphere may be contaminated with chlorine, salt, fly ash, and abrasive materials, any of which are detrimental to good operation. In addition to this contamination, each converter of itself annually liberates many pounds of carbon and copper dust. The commutator, rings, associated brush riggings, risers, and field coils are given a quick cleaning daily by blowing with compressed air. On a monthly schedule each converter is shut down and given a thorough blowing out. In the case of the 2,500-kw units, a canvas tent with an exhauster is installed around the converter while this work is being done. After being thus cleaned, the machines are given a 1,500-volt high potential test before they are restored to service.

The five newer large converters are provided with filtered air supply and equipped with individual exhaust fans to pull the cool filtered air through the machines and exhaust the warm dusty air to the outside atmosphere. This type of ventilating system not only prevents much of the dust and dirt in the atmosphere from *reaching* the machines, but it also materially reduces the amount of accumulation of carbon and copper dust *in* the machines.

Each of the five large converters is completely enclosed in a specially designed steel volute housing (Figure 1) equipped with calibrated air inlets over the commutator and slip rings for the proper air distribution to dissipate the losses in the various parts of the machine. An exhaust fan of about 3,000-cubic-feet-per-minute capacity is connected to each housing to draw the air through the machine and discharge it out-of-doors.

The proper selection of brushes is of prime importance in the successful operation of rotary converter equipment. It has been found that no one grade of d-c or a-c brush will operate satisfactorily on the several ma-

chines. Each requires its own type brush which can be determined only by actual experience. The problem of brush selection is aggravated by two factors: the machines are operated continuously at loads approaching the maximum rating; and the presence of a chemical- and dust-contaminated atmosphere. Cleaner-type brushes are used in certain locations on the converters to give moderate commutator cleaning action.

Where the machines are fully loaded brush tension must be given particular attention in order that the several brushes divide the load properly and in order to prevent undue commutator wear.

The condition of the surface of the commutator is of great importance. Although the prevailing atmospheric conditions are not conducive to the formation of good commutator surface film, relatively good commutator wear is realized. The average time between resurfacings is approximately 18 months. All of the armatures are equipped with mechanical oscillators in order to equalize commutator wear.

There are approximately 7,000 brushes on the a-c and d-c ends of the 14 converters. The life of these brushes ranges from approximately 6,000 to 17,000 hours, and averages about 12,000 hours. The total cost of brush replacement for a 10-year period, ending in 1941, was slightly less than $62,000. These figures are representative of prewar costs and conditions when good brush materials were available. For the past six years, this performance may not have been as good because the machine loads were higher (there was a minimum of spare equipment) and the quality of the brushes obtainable was lower.

About April 1 of this year, an installation of ignitron-type mercury-arc rectifiers (Figure 2) was put into service at the Niagara plant. The equipment consists of two units each of which is rated for 7,610 amperes of direct current at 385 volts. Each unit comprises one rectifier transformer, two 12-anode rectifiers with anode and cathode circuit breakers, and the necessary relaying and control equipment.

The 12,000-volt 3-phase 25-cycle transformers are equipped with 33-position load tap changers to provide direct voltages over the range 135 to 385 volts. Voltages between taps are obtained by firing control; thus, any desired potential between 135 and 385 volts is obtainable.

This equipment has been operated almost continuously since the early part of April in parallel with several combinations of small and large synchronous converters.

Brief experience with this installation has been very satisfactory. Parallel operation with the converters has been quite successful. Some slight difficulty was experienced with the relays which are a part of the system to provide automatic current control by means of controlled firing circuits, but it is expected that this trouble will be corrected promptly.

Another significant installation of conversion equipment in the du Pont Company is one which consists now of eight 450-kw 350-volt motor generator sets. This installation is at the Chambers Works, Carney's Point N. J., (previously known as the Dye Works) and is used in electrolytic production of chlorine. Five of these units were installed about 1929. They were operated then on individual cell lines, and each motor generator set supplied to one line an average of 1,400 amperes at 300 volts.

Later it became desirable to increase the cell line current to about 2,000 amperes. Since then, the motor generator sets have been operated in parallel

Figure 3. Top of a 6-anode mercury-arc rectifier tank

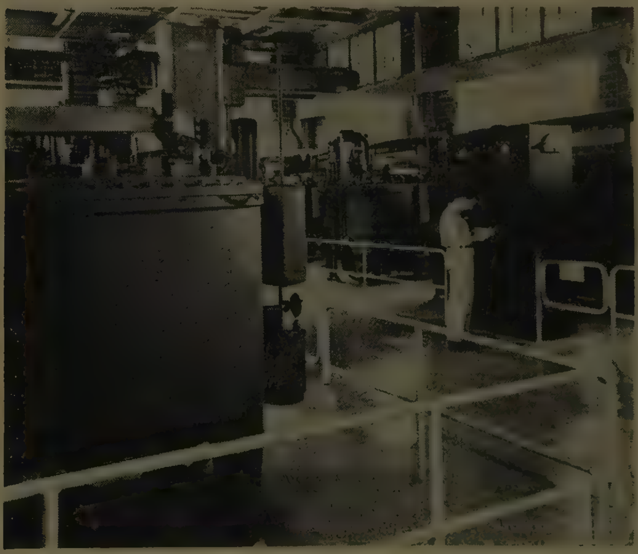

Figure 4. Substation interior showing painted concrete floors to prevent formation of dust

with the several cell lines being supplied from the constant potential bus.

A d-c transfer bus exists which makes it possible to connect any one cell line to a single motor generator set so that the current in that line can be reduced or varied during periods of cell reconditioning.

This installation was made originally in an existing building in which proper ventilation was simply not possible. However, despite the poor conditions under which they were called upon to operate, these machines, originally with class *A* insulation, operated for 10 years, 24 hours per day. At the end of this time, the five machines were rewound with class *B* insulation and the building was rebuilt in order that a proper air filtering and ventilating system could be provided. In 1942 three additional duplicate units were installed.

These motor generator sets are given a daily inspection at which time minor adjustments and repairs may be made, parts which are accessible are cleaned, and yearly each machine is given a thorough overhauling and cleaning.

The first significant installation of metal tank mercury-arc rectifiers was made at the Baton Rouge plant in Louisiana in 1938. This plant was operated then by the du Pont Company; it now is owned and operated by the Ethyl Corporation. This installation was rated for 26,000 amperes of direct current at 515 volts. It was designed for operation from a 13,800-volt 3-phase 60-cycle supply. The equipment consists essentially of four 3,900-kva outdoor regulating autotransformers, four 3,850-kva outdoor combined main and interphase transformers, two 720-cycle indoor air-cooled interphase transformers, eight 1,675-kw 515-volt 6-anode rectifiers with auxiliaries (Figure 3), a-c and d-c switchgear, and metering and relaying equipment.

The installation consists of four operating units, each unit being made up of one oil circuit breaker, one regulating transformer, one combined main and interphase transformer, two rectifiers with auxiliaries, one water-to-water heat exchanger, two d-c circuit breakers, and the necessary metering, relaying, and control equipment. Two of the main transformers are delta-connected on the primary side with a quadruple zigzag secondary and two are delta-Y-connected on the primary side with a quadruple Y-connected secondary. Thus a double 24-phase connection is obtained. Under normal conditions, the four operating units, that is, the eight rectifiers, operate in parallel to deliver the rated d-c load. In an emergency, however, three of the units or six rectifiers are able to carry successfully the rated d-c load with an increase in transformer temperature rise, until repairs can be effected.

In 1940 a second substation was installed which was essentially a duplicate of the first installation. In 1944, one additional operating unit was added to substation number 2, thereby increasing its rating to approximately 30,000 amperes. There is no connection between the d-c sides of these two systems. Each supplies a separate load.

Substation number 1 (Figure 4) has eight rectifiers with their respective transformers located immediately outside the walls. The rectifiers are on the second floor of the 2-story structure. The first floor contains the a-c switchgear, the d-c bus system, the d-c cathode circuit breakers, and certain other auxiliaries. The substation building is separated entirely from the cell room building and is connected by a short bridge. The d-c bus between the rectifier substation and cell room is run underneath this bridge. On the second floor of substation number 1 are located the switchboards for the control of rectifier equipment, distribution switchboards for 220-volt and 440-volt a-c power, station storage batteries, and charging equipment.

Substation number 2 was laid out and installed essentially as a duplicate of substation number 1 except that the control board for the equipment in number 2 was located in number 1 so that both substations could be operated from the same point and by the same operator. Subsequent to its initial installation, the fifth rectifier unit consisting of two tanks with their transformers was added.

These rectifier installations incorporated several new and significant features, some of which are

1. Common voltage control of a group of rectifiers operating in parallel by means of a master control operating on the individual load-ratio-control equipments of the four regulating autotransformers, to give a complete and stepless range of 0–515 volts on the d-c bus.

2. Common voltage control of a number of rectifiers operating on a common d-c bus by means of a master motor-driven phase-shifting rotating transformer to give a 30 per cent reduction of direct voltage by grid control, for a limited time. This control also is effected by one of the switches on each switchboard. As far as is known, this is the only installation having such a system.

3. Unit rating of the regulating and main transformers with a throat connection between the two units. The high-voltage a-c connection to the regulating transformer is made by underground cable, the conduit coming up to a terminal chamber between the two transformers. All of these transformers are water-cooled.

4. A rectifier protective system utilizing medium-speed d-c switchgear with arc suppression on the rectifiers.

5. Twenty-four-phase operation of the station, obtained by transformer connections alone without separate phase shifters.

6. This installation was the first to employ 2-story substation construction. That this is most economical and provides the most satisfactory layout for such installations, is indicated by the fact that nearly every large rectifier substation built since has employed 2-story construction.

As originally installed the backfire or arc-back fault protective system utilized medium-speed d-c switchgear in combination with arc suppression. The arc suppression system was designed to interrupt automatically the feed from all rectifiers by applying negative bias to their grids, in the event of arc-back on one of them, to extinguish the arc in the faulted rectifier, and to disconnect the faulted rectifier from the d-c bus, and then

to restore the normal or unfaulted rectifiers to operation within about one second. This system operated rather successfully with cell line voltages below 400 volts. However, as the cell line load increased to require operation above 400 volts, a high arc-back rate was experienced and many of the arc-backs resulted in complete interruption of d-c power.

Extensive field tests were made in order to determine the cause of the failure of the arc suppression protective system to function above about 400 volts. The fault current on normal rectifiers exceeded the range of reliable suppressive action of the control grids, consequently the normal rectifiers continued feeding into the fault until the medium speed d-c circuit breaker was cleared on the faulty unit. With this failure of arc suppression and sustained flow of fault current, the currents of the normal rectifiers rose to values exceeding their fault current capacity and they in turn arced back and tripped off. This resulted in complete interruption of d-c flow to the cell line.

In order to correct this situation, anode circuit breakers with individual pole tripping were installed on all the rectifiers. The decision to install these anode circuit breakers was based on the premise that they not only would interrupt the current on the faulty rectifier within one cycle, thereby limiting the duration of the fault current on the normal rectifiers, but also would provide the maximum amount of protection to the faulted rectifier and its transformer by interrupting the fault current directly at its source. An added incentive for the selection of anode circuit breakers was the fact that they represented the most recent advance in the development of protective switchgear for rectifiers. They had been developed subsequent to the original installation at Baton Rouge, La., and had been successfully used on several later rectifier installations in similar electrochemical service.

The installation of the anode circuit breakers did *not* provide the improvement hoped for, nor prevent the complete interruption of the cell line current at times. Further tests therefore were made in the field to determine the reason for their failure. These tests brought out two significant facts. The first was that the anode breakers did not interrupt the current on the faulty rectifier in one cycle as it was expected they would do. The reason for their failure to do this was that the fault current on the normal anodes in this rectifier exceeded their fault current capacity so that an arc-back on one anode was followed by successive arc-back on normal anodes feeding into the fault. While the fault on the initiating anode was interrupted by the opening of the pole of the anode circuit breaker to which it was connected, in about one cycle, fault current would continue to flow in the faulty unit as other anodes arced back in succession and they, too, were cleared in about one cycle each. In many cases, three anodes would arc back in turn so that the fault would persist until the cathode circuit breaker cleared the unit. The second finding was that the rectifiers had low fault current capacity. Experience in field and factory tests has shown that most multianode pool-type rectifiers will carry not less than ten times rated current on short circuit for a few cycles. D-c short circuit tests made on the rectifiers at this installation showed that they would carry only approximately three times rated current. In an effort to improve this performance, one of the rectifiers was cleaned and the short circuit tests were repeated. These tests showed that this rectifier was operated in normal service for several months, its fault current capacity fell off again and dropped to about the value observed before cleaning.

This low fault current capacity is of considerable interest because of its departure from usual experience. It is also of interest that although the fault current capacity was abnormally low, the basic arc-back rate was low and the operation of the rectifier otherwise was excellent. This low fault current capacity raised a question regarding the reliability of the rectifier operation. The premise that some form of progressive deterioration was being experienced and that the fault current capacity eventually would fall so low that the rectifiers would be unable to carry rated current was disturbing to say the least. However, several years of experience has indicated that this is not the case and that the fault current capacity apparently does not fall below the value of about three times the rated current. No satisfactory explanation has been obtained yet for the low fault current capacity of these rectifiers and it remains as a definitely singular and unique occurrence.

In order to make the equipment operate successfully under fault conditions, d-c reactors and high-speed cathode circuit breakers were installed later on each rectifier. The d-c reactors were provided to limit the rate of rise of fault current so that the fault current capacity of the normal rectifier would not be exceeded before the fault was interrupted by the high-speed cathode breakers. Furthermore, the high-speed cathode breakers limited the duration of fault current flow into the faulty rectifier to one cycle, despite arc-back on a succession of anodes.

The operation following installation of these protective features has been entirely successful and the rectifiers now are operating with an extremely low arc-back rate, and such arc-backs as do occur do not result in total interruptions.

These two rectifier installations operate at constant current. The voltage is varied to supply the requirements of the number of cells being operated in series. Efficiency of these installations is computed as a function of voltage rather than as a function of current at constant voltage.

It is not possible to give reliable figures on maintenance cost, principally because of the widely fluctuating labor rates; however, in 1945 11,200 man-hours were

expended on maintenance in these two substations and 11,360 hours were expended in 1946. These figures include the maintenance of equipment and buildings as well. Most of the time was expended in preventive maintenance, that is, in inspection and in cleaning of equipment and testing and filtering of transformer and circuit breaker oil.

The cost of the Baton Rouge rectifier installation was considerably less than it would have been for rotary converters. Equipment costs for converters would have been about the same, but the additional cost of building, foundations, and ventilating equipment would have made a rotary converter job at Baton Rouge much more costly than the rectifier installation.

The cost of operating labor (and the cost of maintenance) will be less for the rectifier installation. Baton Rouge presently is being operated with a single attendant for the two stations. Much of the maintenance cost which has resulted at Baton Rouge in the first several years of operation will not be repetitive because it was due to weaknesses in design of parts which have been overcome by new designs and by replacement of parts which had been giving trouble.

In this connection, it is interesting to note the comment concerning rotary converters, made by one of the early operating engineers at Niagara Falls who stated, "Manufacturers were slow to recognize that in electrolytic service, machines were being operated at high loads continuously and for long periods of time. Oftentimes, plants had to keep their machines running for months on end as there were no spares or they could not be connected to relieve all the operating machines. Earlier machines were meagerly designed in some parts and overrated. Insistence on the part of the operators who had to contend with these weaknesses, prompted the manufacturers to be more generous in later machines."

Thus, it appears that even with rotary converters in the early days of their installation, there were certain preliminary weaknesses and errors in design which had to be located and overcome through actual field experience. It is felt that this preliminary period with rectifiers at Baton Rouge has been passed through and that maintenance costs in the future are expected to be much less than they were during the years which preceded 1945.

At Niagara Falls, however, the maintenance costs which are induced by the replacement and grinding-in of 7,000 brushes, the resurfacing, and undercutting of commutators, and the regular cleaning of machines are repetitive operations which will have to be done as long as these converters remain in operation.

Paper Machine Drives

H. W. ROGERS
MEMBER AIEE

THERE are two distinct types of paper machines to be found in the industry; the Fourdrinier machine, named after its sponsor, and the cylinder machine. These machines with modifications are used in the manufacture of all grades of paper and paperboard.

Strictly speaking, a paper machine is not one machine but a combination of several machines, each of which has a very definite function, operating in proper speed relationship with each other, and through which there is a continuous flow of material; in this case a sheet of paper which has practically no strength on the wet end of the machine may have considerable strength after it passes through the dryers.

FOURDRINIER MACHINE

The Fourdrinier machine (Figure 1) consists broadly of four parts; the wet end, the press part, the dryer part, and the calender part. The wet end, or couch, consists of an endless brass and bronze fine-mesh wire cloth which runs over a breast roll at one end and a couch roll at the other end, and is supported in between by a number of table rolls and suction boxes. The wire is driven from the couch roll and a continuous flow of stock consisting of about 199 parts water and 1 part cellulose fiber, flows on it from a stock chest at the breast-roll end. In traveling from the breast roll to the couch roll, a distance of 30 feet or less, 196 parts of water are removed by drainage, capillary attraction, and vacuum. The sheet formed here passes to the press section with about 75 per cent water.

Essential substance of a conference paper, "Paper Machine Drives," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

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Two or more presses comprise the press section, which removes further water from the sheet and equalizes the surface characteristics of felt and wire sides of the sheet. The wet web of paper is transferred from the wire and carried through the presses on woolen felts, whose characteristics vary for different paper grades. From here the sheet is transferred to the dryers at approximately 66 per cent moisture.

Two or more tiers of steam-heated hollow cast-iron cylinder dryers, to which the paper is held in contact by canvas dryer felts, comprise the dryer. In transit through the dryer first one side and then the other side of the paper contacts the heated cylinder surfaces. The paper finally leaves the dryers with a moisture content of approximately seven per cent, about two pounds of water having been evaporated, on the dryers alone, from every pound of finished paper.

With 77 per cent of the world's supply of paper produced in the United States and Canada, and an anticipated annual capacity of 22,000,000 tons by the end of 1947 in the United States alone, the industry has evidenced considerable activity, not only in the building of new mills, but also in modernization and addition of new paper machines to old mills. The industry as a whole presents many interesting problems, but the most important equipment in the paper mill is still the paper machine, the uninterrupted operation of which is paramount.

The fourth or calender part of the machine consists of from one to three calender stacks, composed of highly-polished chilled-iron rolls, with a reel for winding the paper as it leaves the machine. The purpose of the calender section is to smooth the paper and impart the desired finish or gloss to the sheet.

From the reel the finished paper is taken to a winder where it is slitted, trimmed, and wound into smooth even-density finished rolls for shipment, or for further processing.

Machines of the Fourdrinier type are built in sizes from 80 inches wide to 304 inches wide and may run from 400 to 2,500 feet per minute producing from 20 to even 400 tons per day for the manufacture of wrapping, writing, kraft, newsprint, bond, tissue, toweling, toilet, crepe wadding, and facial papers.

The various sections of a machine do not operate at the same linear speed since there is a "draw" or tension in the sheet between sections, which produces elongation varying from six to ten per cent over-all, depending upon the kind of paper being made. Provision must be made to vary the speed of each individual section of the paper machine within certain limits, and also to maintain the relative speeds with extreme accuracy when once adjusted properly.

There are two modifications of the Fourdrinier machine in use, known as the Harper machine wherein the wire travels away from the presses, and the Yankee machine which is distinguished by the use of one large dryer instead of a number of smaller ones. The Yankee machine is used primarily in the manufacture of flat tissue, crepe wadding, and toilet and facial tissue, and is normally a high-speed machine.

THE CYLINDER MACHINE

The cylinder machine (Figure 2) is used for making paperboard, and except for the wet end is very similar to the Fourdrinier machine, but may have many more dryers and calender stacks. Inherently, it is a low-speed machine (650 feet per minute and below), and produces tonnage comparable with the Fourdrinier machine.

It is characterized by the use of one or more cylinders or molds instead of the endless wire cloth used on the wet end of the Fourdrinier machine. These cylinders are covered with a fine mesh wire cloth and rotate in a chest containing cellulose fiber in suspension. Water flows through the wire mesh to the inside of the cylinder, where it is pumped out, thus depositing a fiber mat on the outside, which is picked up on a woolen felt as the cylinder revolves, and carried to the first press and on through the machine. These cylinder molds may be supplied with the same or different kinds of stock. In the case of a multicylinder

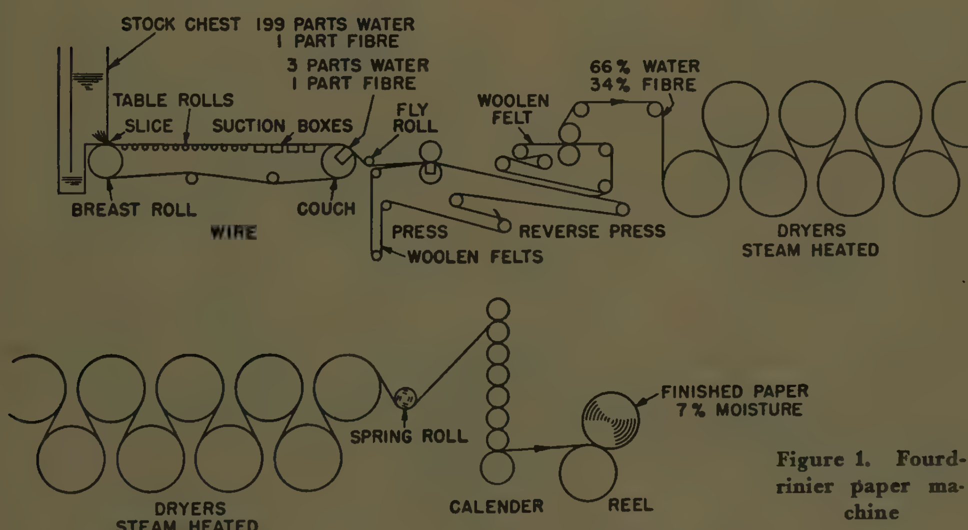

Figure 1. Fourdrinier paper machine

machine, the webs are picked up successively by the felt, one on top of the other, before entering the press section. This permits wide variation in thickness or weight of the finished sheet, as well as variation in the kind of stock used for the different layers.

The foregoing descriptions are general in character and cover the more simple types of machines, but there are many modifications in the make-up which may include such sections as smoothing presses, breaker stacks, size presses, coating presses, and sweat or cooling dryers, all of which are considered a part of the machine, and except for the cooling dryers, are subject to the same accurate speed control as the other sections.

A paper machine never is started as a unit, but rather each section is brought up to a predetermined speed in sequence. When the whole machine is running, stock is put on the wire and carried through the machine, first as a narrow strip and then as a full-width sheet.

Since the output of any paper mill, and therefore its profit, is dependent solely upon the continuous successful operation of the paper machine, it is not only the most important machine in the industry, but also the most interesting. It, therefore, has received a great deal of engineering attention, to the end that it may be operated without interruption and produce a uniform high-quality product.

TYPES OF DRIVE

There are but two types of drive in general use on paper machines: the mechanical, or line-shaft drive, which is in reality a group drive; and the sectional electric drive. Where mechanical drives are used some form of motive power is connected to the backline shaft such as a steam engine, steam turbine, or electric motor; but with the sectional electric drive the back line shaft, with its component parts, is eliminated and individual motors are connected directly to each machine section.

Prior to 1919 and the introduction of high-speed machines, most paper machines were driven mechanically from a backline shaft with a pair of tapered pulleys, belts, bevel gears, and clutch interposed between it and each section of the machine, some form of motive power being used to drive the line shaft. It is this type of drive rather than the motive power, which may be either steam or electric, that constitutes a mechanical drive.

Both the constant-speed and adjustable-speed steam engines were in general use, and it was not an unusual thing to see a pair of large tapered cone pulleys, perhaps 12 to 15 feet long, interposed between the constant-speed steam engine and the line shaft to permit operating the machine over a reasonable speed range.

Where mechanical drives are concerned, it appears that the adjustable-speed steam engine practically has been replaced by the adjustable-speed mechanical-drive turbine or the single-motor drive with Ward Leonard control. While most of these are limited to small capacity (up to 500 horsepower), a single-motor drive of 900-horsepower capacity recently has been furnished, and several mechanical-drive turbines of 2,000 horsepower capacity are in operation on high-speed machines.

Needless to say, both the mechanical-drive turbine and the single-motor drive have their place in the industry and many of them are in successful operation. The mechanical-drive adjustable-speed turbine, however, is of the noncondensing type, and since the exhaust steam is used for drying the paper a careful check of the steam conditions must be made to be sure that a reasonable balance exists between the power requirements and the heating requirements. It is not always possible to secure this balance, and there may be instances where the turbine is not applicable from an economic standpoint. Where used, it is very successful, and with its electric governor, extremely close speed regulation is maintained.

Mention has been made of the single-motor electric drive and while some few a-c brush-shifting motors have been applied to small machines, this application in the Americas is confined largely to the use of d-c motors with either adjustable-voltage Ward Leonard

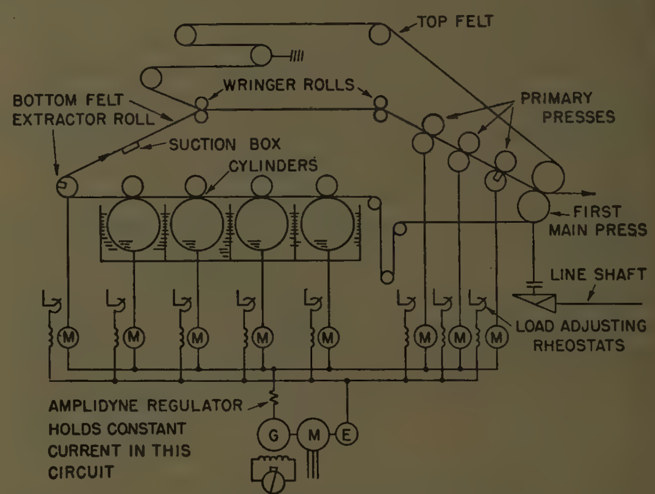

Figure 2. Cylinder paper machine with auxiliary wet-end helper drives

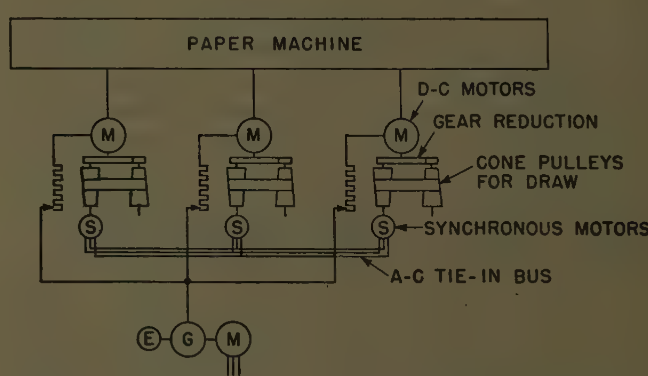

Figure 3. Sectional drive with synchronous motor tie-in

control or a combination of adjustable-voltage and motor-field control.

With the single-motor drive a synchronous motor generator set with Ward Leonard control is used generally and since extraction steam from the house turbine is used for drying, there is no question of steam balance; also this system may be more economical than the mechanical-drive turbine since the water rate on the large condensing house turbine is much lower, and it is always advisable to generate as much power as possible from the steam produced.

In 1919 the great demand for increased production heralded the introduction of the high-speed paper machine, and since the existing mechanical drive was not adequate to meet the situation, the sectional-electric paper machine drive came into being and continued for many years to be the only solution to the driving of high-speed machines. During the intervening years, however, the mechanical drive has been improved, and has increased in capacity to such an extent that it is adequate to meet the needs of many present-day machines. On drives of this type, the limitations of the mechanical drive become apparent, especially on large machines where auxiliary electric drives (Figure 2) commonly are used as helpers or on certain sections of the machine, the driving of which is definitely beyond the scope of any type of mechanical drive. The so-called helper drives, except for those used to supplement a heavy machine section and relieve the duty on mechanical clutches and gears, are common to both the mechanical and the sectional electric drive.

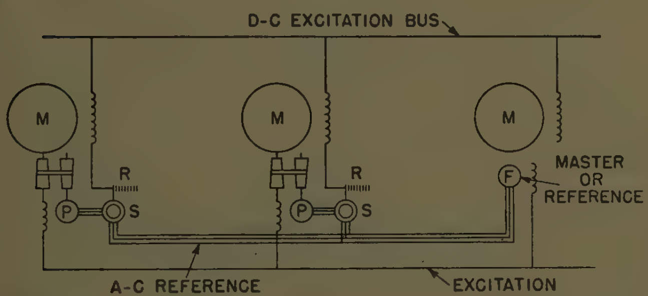

Figure 4. Synchronous regulator of the differential type

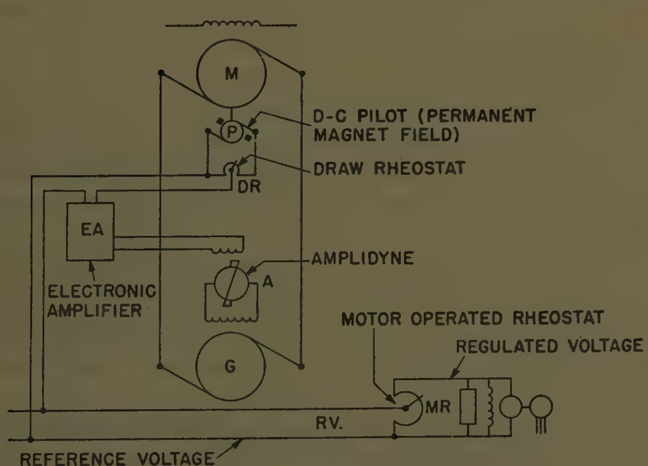

Figure 5. Speed regulator

SECTIONAL DRIVE

The sectional electric paper-machine drive, wherein each section of the paper machine is driven by an individual motor, came into being at a time when no existing mechanical drive could meet the demands of high speed, and appears to be holding its well established place in the industry in spite of the many improvements made in mechanical drives. Recent comparative costs seem to indicate that the sectional electric drive is less expensive than the motor-driven mechanical type. Also, the sectional drive appears to be applicable equally well to both high-speed and low-speed machines, and cylinder machines, as well as to Fourdrinier machines.

Extensive use has been made of the a-c brush-shifting motor for sectional paper-machine drives in Europe, but except for a few applications of small capacity motors to narrow slow-speed machines, applications in America have been confined to the d-c shunt motor operating on an adjustable-voltage system of control. This system has been economically sound and very successful since the paper machine is inherently a constant-torque machine on all sections, except the calender where the torque requirement is greatest at low operating speeds.

The original sectional drive in the United States (neglecting the one put in service in 1909) is shown in elementary form in Figure 3. Each individual section of the machine was driven by a low-speed d-c motor, connected through a set of gears and cone pulleys to a synchronous motor, with the synchronous motors tied together electrically. The synchronous motors were approximately 20 per cent of the d-c motor capacity, and with the belts on the cone pulleys properly set for the desired "draw," they held the several sections of the machine in step by "brute force."

The accuracy of this drive was affected somewhat by belt slippage, but in this case the belts were designed to give a maximum of 0.3 per cent slip with a 20 per cent load change on the d-c motors, and provision was made for adjusting the motor field to maintain the synchronous-motor load at near zero. Many of these drives are still in successful operation after 25 years of service.

SYNCHRONOUS REGULATORS

The next step was the elimination of the synchronous motors with cone pulleys and belts (or their equivalent) as a power tie and the introduction of the synchronous regulator. With this arrangement each paper-machine section is driven by a d-c motor, and speed relationship is maintained strictly by synchronous regulators acting on the field of the respective d-c motors.

Figure 4 illustrates the widely used system of this type.

A small a-c pilot generator P is connected to each section motor M through a pair of small cone pulleys and a belt. The frequency generated by the pilot generator is used to energize the rotor of a self-synchronous motor S or equivalent, of the speed regulator; the stator of the self-synchronous motor, or equivalent, is connected to the "master" frequency source F. When the two frequencies match, the regulator is stationary. If, however, the speed of any section motor departs from the set value, the resultant change in frequency of the pilot generator will cause the self-synchronous motor to move, thereby changing the excitation of the section motor through resistance R and correcting the speed.

Since the self-synchronous motor, or its equivalent, will rotate until the stator and rotor have rotated through the same number of degrees, this is, in effect, a differential or position regulator causing each section to deliver a specified length of paper in a specified length of time: any temporary deficiency in speed is compensated through action of the regulator by an equivalent overspeed.

The chief advantage of synchronous regulators is the relative simplicity and extreme long-range accuracy under steady-state conditions. On the other hand, this type of regulator, being a differential type, is inherently not fast enough to take care of instantaneous load changes without introducing the danger of hunting at the same time. The wider the speed range over which the paper machine operates, the greater this danger becomes.

SPEED REGULATORS

As far back as 1922–23 experimental work was conducted on an electronic speed regulator, but the continuation of this work was abandoned temporarily because of lack of any assurance regarding the expected life of the vacuum tubes. It was not until 1937 that the electronic speed regulator really came into use as a successful means of coping with instantaneous load changes. From that time forward, a number of them were installed on several paper machines throughout the South and finally in 1941 a complete sectional drive with electronic regulators was put into successful operation.

As shown in Figure 5, each d-c section motor M is equipped with a permanent-magnet d-c pilot generator P, the voltage of which is a measure of speed. This voltage is compared with a precisely controlled reference voltage RV and the differential voltage, if any exists, is amplified: first, electronically through the amplifier EA, and then by an amplidyne A which controls the field of the generator G supplying power to the section motor. When the generator supplies power to several section motors, the amplidyne is used to control the motor field.

In this manner any deviation of the motor speed from a set value is corrected quickly. The reference voltage may be adjusted by means of the motor-operated rheostat MR to change the speed of the machine as a unit (up or down), the speed of the several sections remaining in fixed relationship to each other. Draw adjustments on any section motor may be made by the "draw" rheostat DR in the pilot-generator circuit.

The electronic-amplidyne regulator is not inherently synchronous as is the differential self-synchronous type. It is a speed regulator rather than a position regulator, as is the latter. Its accuracy is, however, ample for paper machine service, and its speed of response to transient load changes is superior to that of other types. Its stability (antihunt performance) can be maintained readily throughout a wide speed range.

All synchronous speed regulators are of he differential type, depending upon a change in speed which produces a phase displacement to make them function, and this speed change persists until the phase displacement disappears. Its speed of response is definitely a function of the differential in speed and this slowness in response may cause difficulties on the machine, such as wrinkles in the paper. By the same token, response to "draw" changes are slow, and an operator may overshoot the mark and cause breaks because he does not see immediate response. The electronic-amplidyne speed regulator is quick in action, instant in response, and will not only take care of instantaneous load changes, but gives immediate evidence of readjustment in "draw."

MULTIPLE GENERATOR SYSTEM

Up to this time all sectional paper machine drives, except two on wide-range machines and a goodly number on tissue machines, have been of the single generator type either with or without an auxiliary starting generator. In 1946, the recognized advantages accruing from the use of the multiple generator system (Figure 6), wherein each sectional motor has its own individual generator and speeds are controlled by armature voltage rather than by motor shunt field, led to its adoption on a large number of new machines.

The adoption of this system is in no sense a criticism of the single generator system, many of which are in successful operation and may continue to be used for certain grades of paper, but rather it is further progress in sectional paper machine drives and is recommended highly because of its many advantages, especially for machines operating over wide speed ranges on a wide variety of products.

In flexibility it far surpasses anything thus far offered to the industry because it is possible to start, or stop, one or all sections at the same time, and simultaneously operate any section at whatever speed may be required Since each motor has its own individual generator, load disturbances are not transmitted to other sections. The section motors operate at all times on full field with constant torque per ampere throughout their

speed range and need not, therefore, be derated as is the case with the single generator system. Motor speed is controlled by armature voltage which is much more stable, and since the speed regulator operates on the generator field to control voltage, it is not necessary to build so much range into the regulator.

The reference voltage, which is isolated from all disturbances, controls the speed of the paper machine and may be adjusted up or down to meet the speed requirements. It is this reference voltage which is compared with the voltage of the pilot generators on the section motors, the difference being introduced into an electronic amplifier which controls, the field of an amplidyne and thereby the generator field to maintain extremely close motor speeds.

The multiple generator system simplifies the wiring greatly, has fewer devices, permits the use of a shorter control board, and as previously stated, adds the utmost in flexibility of control and general operation. Yet, it is not new to the paper industry because two of these have been operating continuously for the past 20 years with a minimum of maintenance. At the moment there are a large number of these drives on order for both Fourdrinier and cylinder machines, some of which will operate over wide ranges in speed.

HELPER DRIVES

Perhaps the most interesting of these drives is the suction primary couch roll which is located ahead of the main couch roll and has a wire wrap not exceeding 15 degrees. This roll must be driven at wire speed without any slippage which would cause undue wear or perhaps break the wire. The torque this motor delivers is definitely a function of vacuum in the couch-roll box; the greater the vacuum, the more the motor can pull without slippage. Therefore, it is equipped with a vacuum-controlled current regulator.

Auxiliary motors sometimes are used on the wire rolls but these are of small capacity with a dropping speed characteristic and may be operated in parallel with the couch motor. Fly-roll motors also have been a more recent adjunct. They are used primarily to bring the roll up to speed on high-speed machines, the paper being sufficient to keep them going, once up to speed.

With the introduction of the dual press and the addition of top rolls to dual presses, one or more motors have been used to absorb the friction load and prevent slippage at the nips. In sectional drives these motors may be operated from the same generator as the main press motor, but they are equipped with field rheostats for load adjustment while the main motor only is speed controlled. With a mechanical drive on the main press roll, these helper motors would be supplied with power from a motor generator set and a current regulator used to hold the current constant, regardless of speed. Top roll drives for standard presses are a similar application and subject to the same treatment.

The advisability of adopting helper motors for the breast roll on the wire already has been considered, and several dandy-roll drives and lump breaker roll drives already have been applied. Individual motors frequently are applied to Feeny dryers (felt dryers which are not geared to the dryer train), but motors may be operated in parallel with the main dryer motors. They have a dropping speed characteristic, and no attempt is made to regulate them since their only function is to take the load off the dryer felt, and they readily adapt their speed to the condition of the felt.

Size presses and breaker stacks, which require little power, and coating presses, of which there are a variety, generally are considered a part of the paper machine and their speed must be controlled accurately.

Cooling dryers or sweat dryers are equipped with motors not customarily regulated since the motor function is to start the dryers and bring them up to speed, after which the sheet, being fairly dry and strong, will keep them in step.

Perhaps the most common use for helper motors is on the wet end of a cylinder machine (Figure 2). Such drives commonly are called auxiliary wet-end drives. The make-up of cylinder machines varies widely depending upon the weight of paperboard being made. In any event the first press felt is common to a number of cylinder molds, extractor rolls, wringer rolls, suction boxes, and primary or baby presses, most of which were

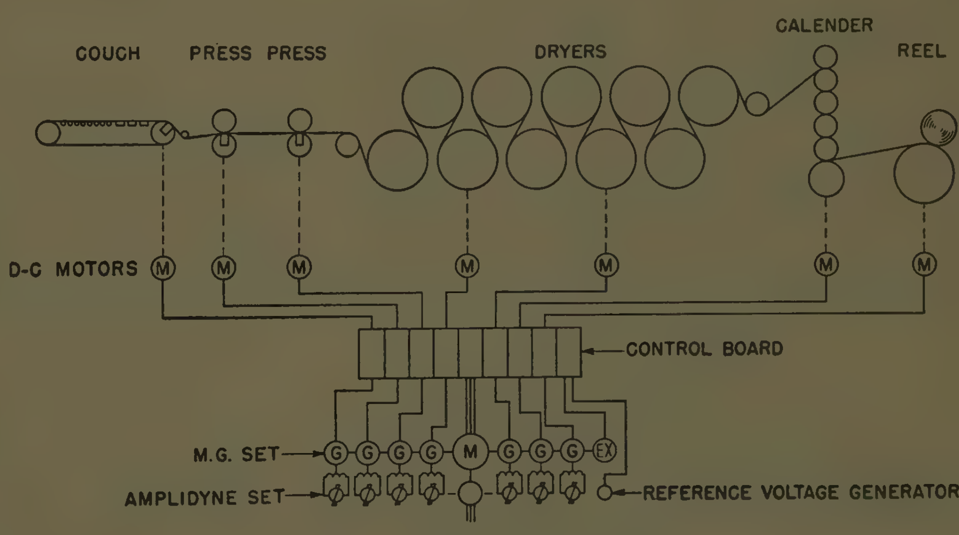

Figure 6. Multiple generator system

slip-driven by the felt before the use of the "wet-end" helper drive.

The use of helper motors on such sections relieves the tension in the felt, permits the use of a lighter felt designed for water removal qualities rather than for power transmission, lengthens the life of the felt, and reduces the cost per ton of felts. Motors for this service have a dropping speed characteristic with shunt-field control for load adjustment and are operated in parallel from a common source of power equipped with a current regulator which maintains constant current on the group, regardless of speed.

Strictly speaking, the couch, presses, wringer rolls, and pressure-roll motors on a Yankee tissue machine, which also has a common wet-end felt, are helper motors controlled in the same identical manner, the Yankee dryer and following sections being the speed-controlled units.

There are, of course, many other motor applications which apply directly to the paper machine, but they are auxiliary motors rather than helper motors and are generally of the a-c type. They involve such applications as the wire shake, suction-box oscillators, felt tightness, roll lifts, and calender lifts, and operate only intermittently.

Electric Equipment Maintenance

W. L. ELIASON
MEMBER AIEE

Electrical men who have the operation and maintenance of equipment under their supervision realize the importance of an adequate maintenance schedule. Although this article does not outline a definite maintenance schedule for any one mill, it does provide basic information from which any mill electrical supveriso r can draw up such a schedule to meet the requirements of local conditions.

THE OLD-TIMERS who have been responsible for supervison of electric equipment within the last 20 to 30 years, and who have seen the equipment under their supervision increase twofold and threefold, continually are fighting for a maintenance schedule to meet local requirements. It is impossible to place too much importance on a proper maintenance schedule since to err is human and an employee can accomplish only a certain amount of work. With this in mind, even with a satisfactory maintenance schedule, it is necessary at all times to keep pressing for detailed information on items to be included in the schedule.

The maintenance schedule should be compiled in as simple a form as possible to provide the necessary information to give the desired results essential to continued operation of the mill. The following will give basic information from which a maintenance schedule can be compiled.

NUMBER SYSTEM

A common reference number should be assigned to each motor and control throughout the mill. These numbers should be allocated by department to facilitate checking on reported troubles on equipment by mill number. The departments can be considered as a whole or can be subdivided, such as sulphite mill into acid plant, digester building, sulphite screen room, and so forth. The numbering of equipment in a mill should start either at the receiving or the shipping end, progressing in a systematic manner to completion.

CARD RECORD

For all motors a card file should be compiled and filed according to mill number, and a second card file should be compiled and filed according to horsepower. All motor file cards should record the following information: feeder number, plant number, number of poles, horsepower, speed, serial number, type, phase, frequency, voltage, amperes, manufacturer, present location, driven machine, type of drive, unit base or rails, shaft diameter, bearing size, bearing type, model or frame size, drawing list (if available), rotor number, and rotor drawing list (if available). Under winding data the following information should be included: winding connection, type slot, number of groups per phase, number of coils per group, coil span, number of turns per coil, size of wire, and weight of copper. On the reverse side of the

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card the following information should be entered: dates cleaned, dates rewound, dates repaired, dates bearing changed, and location changes.

Another card file should be compiled and be filed according to horsepower rating for control apparatus. The control apparatus record cards should have complete data on the equipment as follows: mill number, horsepower, current, frequency, serial number, type, phase, manufacturer, drawing list (if available), catalogue number, size, form, safety switch data, relay data, and on the reverse side of card, a record of dates repaired and location changes.

The card record for spare motors and control apparatus should be as complete as for the afore-mentioned card files and it is suggested they be filed under horsepower.

The suggested methods of filing the record cards do not have to be followed necessarily. Each mill or plant will have the filing system which meets its own requirements.

OPERATING RECORDS

1. Greasing antifriction bearings.
2. Weekly load reading on all motors under load.
3. Insulation resistance tests periodically.
4. Air gap checks periodically.
5. Condition of windings monthly (grease, dirt, dryness).
6. Full load speed checks.

Sleeve bearings should be checked daily and oil added if necessary. Care must be exercised in the amount of oil to be added, taking into consideration the location of oil gauge, type of gauge, and rotation of motor shaft. Greasing of antifriction bearings will be determined by experience as regards frequency, using as a basis the manufacturer's recommended time of three to six months. Where possible and where operating experience indicates, antifriction bearings should be cleaned thoroughly and repacked with grease once a year. The bearing housing must not be packed more than half full for satisfactory operation as a general rule. An insufficient or excessive amount of grease will cause the bearing to heat; also cleanliness of grease must be watched to prevent heating and damage to bearings due to grit and dirt. Items 3, 4, and 5 are checked by mill sections during the Sunday shutdown, or whenever possible if no Sunday shutdown occurs, but must be scheduled. Records are made of check-up and repairs scheduled for the following week-end shutdown or the next shutdown period. Should the inspection show up an emergency repair condition, then the work must be done during that shutdown period. Load readings are valuable to correct overloading and for increasing capacity of underloaded machines.

MOTOR MAINTENANCE

1. Cleaning of windings
2. Determination of winding repairs.
3. Cleaning of bearings and oil wells.
4. Spray varnishing of windings.

The periodic check-ups made will determine the maintenance necessary. For cleaning the motor windings and bearings, the insurance underwriters have approved several cleaning fluids. The method of applying these fluids is obtainable from their manufacturers for best results. While the motor is disassembled for cleaning, the rotor bars should be checked for loose bar connections, particularly if the motor full load speed is low. All repairs should be reported for the file card record.

CONTROL MAINTENANCE

1. Examination of power and control contacts.
2. Checking of starters for proper oil level.
3. Checking of starter oil for water content.
4. Examination of safety and disconnecting switches.
5. Periodic check-up of relay operation.
6. Examination of solenoid and contactor coils for deterioration.
7. Periodic check of autotransformer coils.
8. Report of all repairs in detail.

All of the afore-mentioned items are important to maintain continuous operation. Safety switches must be examined periodically for ease of operation to insure positive opening of all switch blades. This is very important because some safety switches are constructed in such a manner that the blade contacts are not visible. As a safety precaution, voltage should be checked on the motor side of the safety switch.

POWER FEEDERS

1. Examination of insulators and supports.
2. Examination of potheads, cables, and supports.
3. Examination of manholes for dirt and water.
4. Checking of cable loads.
5. Report of conditions as found in detail.

Generally the afore-mentioned items do not require much attention as long as cables are not heavily loaded or overloaded. This check does not require much time but must be periodic to insure safe operating conditions.

LIGHTING SYSTEM

1. Examination of fuse contacts for heating.
2. Examination of branch circuit switches for heating.
3. Examination of contacts on mains.
4. Examination of lighting fixtures for cleanliness.
5. Examination of bulbs for cleanliness and age.

Good lighting is one of the best aids to good housekeeping, and also improves production. All lighting should have a cleaning schedule to maintain efficiency.

POWER SWITCHING

1. Control and operating mechanism inspection.
2. Relay operation and contacts inspection.
3. Main breakers and disconnect switches inspection.
4. Inspection of all load parts for heating.
5. Report of all unusual conditions.

Power switching apparatus, unless heavily loaded or overloaded, would require inspection once in six months or possibly once a year, depending on load conditions and operating frequency.

POWER TRANSFORMERS

1. Oil levels and leakage to be watched closely.
2. Oil conditions to be inspected.
3. Transformer temperature must be checked and recorded.
4. Cooling water systems checked and maintained.
5. Insulator bushings to be examined carefully.

Insulator bushings of power transformers as well as distribution transformers must be kept as clean as possible. Oil levels, leakage, and cleanliness is most important, together with prevention and elimination of any water accumulation. Cracked insulators must be replaced at the earliest possible time to prevent serious trouble.

GENERAL

1. Material available in stores department.
2. Maximum and minimum quantities of stock to be set up on essential materials.
3. All electrical stores material to be in one section of the store room with adequate identification marking.
4. Cleanliness of all electric equipment.
5. Periodic general check-up and repair of miscellaneous equipment to be determined by operating experience.

Careful and thorough maintenance of electric equipment is as important as the engineering and selection of the best equipment to meet the operating requirements. In fact, the best equipment will not give continuous satisfactory operation without proper maintenance, just as inferior quality material only can produce an inferior product. Electric equipment and the accompanying maintenance no longer can be considered a necessary evil or just one of those things that has to be put up with. It must take its rightful place in the list of important production equipment and materials. All are dependent on each other to the extent that inferior quality in either motive power, production machinery, or materials, will result in a product of inferior quality.

Industrial Research in India

Long considered one of the industrially backward countries of the world, India rapidly is taking steps to remedy this condition, according to the *Foreign Commerce Weekly*, through a program of government-sponsored research. This program has been operating since 1940 and is interesting to review in the light of the large amount of discussion on government-sponsored research in the United States.

Industrial research in India is centered in the Council of Scientific and Industrial Research, which was established by the Central Indian Government in 1940. The council's scope includes all branches of natural science and their application to industry. Its functions are

1. It carries out research in its own establishment for the benefit of the country as a whole and to meet the requirements of government departments.
2. It encourages research in industry.
3. It promotes fundamental and applied research in universities and research institutions through a system of financial grants.

To further the last-named activity, the council has set up more than 20 research committees to examine research plans submitted by universities and research institutions and to make recommendations. They assist in developing organized research in specified fields of admitted importance, and in training research personnel. Substantial grants have been made to the leading Indian universities, and some 122 research schemes were financed by the council in 1945.

The council currently is engaged in carrying out a five year program of research calling for a bulk grant of 60,000,000 rupees (approximately $18,000,000). The plan is the result of a survey made at the end of the first five years of the council's existence by its industrial research and planning committee.

The committee's major proposals included:

Establishment within five years of a national chemical and a national physical laboratory, as well as specialized laboratories for industrial and scientific research in the fields of food, metals, fuels, glass and silicate, oils and paints, buildings and roads, leather and tanning, industrial fermentation, and electrochemistry.

Establishment of a technological institute along the lines of the Massachusetts Institute of Technology in the United States.

Setting up a network of corresponding research organizations in provinces and major states.

Encouragement for industries to set up their own research organizations on a corporate basis by exempting the research expenditure of funds from income assessment.

Setting up a central research organization—the national research council—as an autonomous body with membership representing science, industry, education, labor, and government.

The Council of Scientific and Industrial Research took immediate steps to carry out the proposals of its planning committee. Prompt approval was given for five of the national research laboratories envisioned by the plan—physical, chemical, fuel, metallurgical, and glass and silicate research laboratories. Further support to universities no doubt will lead to the establishment of the remaining suggested laboratories.

In December 1946 the scientific consultative committee which had been set up in December 1944 was reconstituted. Its membership was doubled and now is composed of representatives of all important branches of scientific research—ten official and ten nonofficial.

The functions of the committee are twofold: to advise the government on all general questions of policy relating to research throughout India, and to co-ordinate all research. The committee will be attached to the Department of Industries and Supplies.

Electric Equipment in the Finishing Room

F. WINTERBURN

The diversity of equipment used in any finishing room depends upon the types of paper being produced in the mill, and also on the amount of fancy finishing desired. Some mills such as those producing newsprint normally confine their finishing operations to rewinding and splitting defective rolls; others, such as those in the fine paper field, go in for a multitude of finishing or secondary processes which change the visual or physical characteristics of the original paper. These may be something vastly different, but, nevertheless, very important in their relation to the end use of the paper.

MANY of the older paper mills have water power and steam generating installations whereby an abundant supply of cheap d-c power is available for finishing room service. In this instance d-c motors can be used to good advantage. However, many mills purchase electric energy, and it is usually more economical to adopt a-c equipment for a majority of the machinery in the finishing room. As most finishing room equipment consists of small units, it is advantageous to adopt a system of individual drives and the low-voltage induction motor provides a very satisfactory installation. Where direct current is available, the shunt-wound motor is exceptionally successful. The equipment to be found in the finishing room of fine paper mills is dependent upon the grades of paper produced, but most of these departments will have such machinery as supercalenders, cutters, trimmers, embossers, platers, and some will have, in addition, coaters, conditioners, and other special apparatus for some particular purpose. As each machine is required for a different purpose its drive must be designed to conform to the conditions of its operation. Therefore, a study of each unit is necessary.

SUPERCALENDERS

Most grades of paper to be processed for finishing leaves the paper making machine in rolls which are trimmed to a definite size and, if supercalendering is required, it is run off before cutting into sheets. Supercalenders are used to produce a high gloss finish on paper by means of an alternate series of chilled-steel and paper-filled rolls which are driven by friction from the bottom or drive roll. High pressures at the nips, the friction (and consequent heat), and the moisture in the paper combine to give the desired finish. Among the most popular types of drives used for this equipment are the mechanically connected gear train, the wound-rotor motor type, and the brush-shifting motor installation. The gear-driven type of machine is a clutch-operated gear train, providing slow and fast speeds. The machine is started from a loose pulley for threading and then to high speed by means of a clutch. There is no variable speed possible with such an installation, and any kind of motive power will suit the drive as a line shaft is necessary to complete this unit. A standard squirrel-cage induction motor of from 50- to 150-horsepower will give satisfactory results, and a line starter or compensator will take care of the starting apparatus.

Considerable experimenting has proved that excellent supercalender operation can be expected from a wound-rotor induction-motor drive. Directly connected to a gear reducer and controlled by a liquid rheostat in the secondary winding, a wound-rotor motor will give very good results. A conventional cross-the-line magnetic starter is used in the primary circuit of the motor and the stepless control obtained by the liquid controller provides smooth acceleration and easier threading through the series of rolls. In this way broke is reduced to a minimum and the number of breaks in a roll of paper is lessened. The type of enclosure and bearings of the motor for this operation depends upon its location. Most installations could use the skeleton frame sleeve bearing motor with dependable results.

Brush-shifting a-c motors have been used to a limited extent on supercalenders. This installation usually consists of a main drive motor for the higher speeds and a smaller unit for threading. The main drive motor might be from 50 to 100 horsepower. The threading motor is started by means of a magnetic contactor and a small pilot motor automatically moves the brushes to top speed position. Top speed of the threading motor is necessarily very slow in order that the sheet can be threaded through the series of rolls.

An inching switch is provided for the threading motor which is independent of the pilot motor and allows the motor to be inched without the pilot motor moving the brushes.

When the threading motor reaches its maximum speed, the main motor is started and takes over. An overspeed clutch is provided for this purpose. The main

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drive pilot motor has a preset control whereby any predetermined speed can be obtained. The operator sets the control to the speed he desires, presses the starting button, and, when the threading motor comes up to its maximum speed, feeds the paper through the supercalender. When the sheet is set up properly the operator presses a second start button and the main drive motor takes over the operation. A separate control is provided so that the speed can be changed independent of the preset control. The entire installation consists of a complicated control system requiring much maintenance. Considering the high initial cost, it does not warrant its preference to the wound-rotor induction motor. Any of the foregoing installations can be replaced with a shunt-wound d-c motor, and with a well designed control, either electronic or relay system, all the advantages of the other drives can be had. This, of course, is dependent upon a cheap source of direct current.

CUTTERS

While still in rolls the paper, which may or may not have been through the supercalender, is cut to size, either to go out untrimmed, or to be trimmed in a subsequent operation depending upon customers' requirements. This is accomplished by unwinding one or more rolls into a machine called a rotary cutter. For many years cutters were driven at a speed of about 250 feet per minute by motors in 5- and $7^1/_2$-horsepower capacities. When it was decided to increase the speed to 500 feet per minute, it was necessary to increase the size of the motor to 15 horsepower. Where direct current is not available and the use of the shunt-wound motor is not permissible, wound-rotor induction motors can be used to good advantage. Many of the a-c motor installations are controlled by a step-by-step drum controller and grid resistors in the wound-rotor circuit with a small oil circuit breaker in the primary winding. The standard drum controller was found to be inadequate for speeds up to 500 feet as the speed change per step was far too great and the acceleration was too fast to handle the sheet. This resulted in excessive broke and lost time. When the high speed range was reached it was noted that the best speed often would fall between steps and it was necessary to operate at a reduced speed. To offset this disadvantage a magnetic line starter was substituted for the manually operated oil circuit breaker and a liquid rheostat replaced the drum controller. The liquid controller was designed to suit the desired speed range and, with a caustic soda electrolyte with a Baumé of 1.0, excellent results were obtained. With this type of control smooth acceleration takes place and the speed can be adjusted to the point of maximum output with the resulting reduction in broke.

TRIMMERS

Large volumes of fine paper that is cut to customer requirements are shipped for final trimming after printing or other subsequent processing, but other paper is trimmed in the mill finishing room. In recent years it has become increasing important for the finished sheet to be of uniform size, therefore, after the paper has been cut into sheets of varied dimensions by the cutter, the final trimming is done on various types of trimmers. As these machines are operated at constant speed, the standard squirrel-cage induction motor will give suitable service. As the process of trimming is similar to any other shearing operation, some advantage would result from the use of a high slip rotor. Finished sizes of paper to be trimmed are determined by the distance between a movable back-stop, against which sheets of paper rest, and the cutting knife on the trimmer. Many finishing rooms are equipped with trimmers which automatically set the back-stop at exactly the same spot for each cut as the ream of paper is trimmed. This is done by means of a number of movable, double contacts which the operator sets up for each order on an overhead rail. The double contacts are required because the back-stop moves at high speed immediately after each cut and then drops to extremely low speed for the last half inch of travel after hitting the first of the double stopping contacts. The back-stop then moves slowly into its final and exact position. This is done without the aid of the operator. The change from high to low speed, and the reverse, is accomplished by solenoid-operated gear shifting mechanism and the entire control system is operated at about 24 volts alternating current. Low voltage is necessary because the control circuit is exposed to the operator.

PLATER MACHINERY

There are various means employed for pressing different types of fancy finishes into sheets of paper and a common method is the use of a plater. In producing a linen-finished stationery sheet, a pile of about 50 or 100 sheets of paper is made up with a layer of linen between each sheet of paper so that the surface effect of linen is pressed into the paper. The pile, or book as it is called, has sheets of steel or zinc interspaced at frequent intervals between the sheets of linen and also at the top and bottom of the book. By means of a clutch or other reversing arrangement the operator passes the book back and forth between a pair of rollers under several tons of pressure. Various cloths are used for other designs. As the process is purely a constant speed operation, electric equipment similar to that used on the trimmer can be used. A squirrel-cage induction motor with a high slip rotor will give good results and standard cross-the-line starting equipment will prove to be quite suitable for this purpose.

Belt-type linen finish machines require controlled acceleration, therefore, a variable-speed wound-rotor induction motor is necessary. Here again the liquid controller will give better service and higher production than the grid resistor type.

EMBOSSING

In the embossing operation the desired surface finish is imparted to the paper while it is in the roll instead of sheet form. Paper is fed into the nip between two rollers, one of which has the desired surface finish engraved upon it. The untreated roll of paper is started through at a very slow speed and is accelerated quickly to several hundreds of feet per minute. In order to avoid breaks in the paper it is extremely important that this acceleration be smooth and steady.

At the higher speeds of today, it has been found that step acceleration, which is achieved by the grid resistor type of controller, is not desirable, and, as for cutters, the maximum good operating speed cannot always be be reached. A standard wound-rotor induction motor with cross-the-line primary starting and a liquid secondary controller should prove the best installation.

COATING

In order to produce a high-gloss smooth finish for some types of magazine paper and graphic art work, a process known as coating is required. Coating materials are in liquid state and various methods have been developed to deposit a film of this mixture on the sheet. It is extremely important that the coating be applied evenly and that the caliber of the finished sheet remain within the tolerances allowed.

One of the older methods of applying the various types of coating, the brush-coating method, consists of unrolling the paper through a series of vats filled with china clay and casein or other similar fillers, and then passing a variety of brushes over the coating which spread it uniformly over the sheet and remove excess material. Before the wet coated paper can be rerolled, it must pass through some form of slow drying because, if it dries too rapidly, wrinkles appear in the sheet and it will be useless for printing. Ordinarily a long tunnel is provided through which the paper is carried on spars at a slow rate of speed. Temperature control is necessary to dry the coating at a proper rate, and, as this operation is necessarily one of very slow speed, a constant speed drive can be used and any standard constant speed motor and auxiliary apparatus will be suitable. As some speed variation is advantageous, a wound-rotor induction motor or shunt-wound d-c motor should prove an asset. In an induction motor, a drum-type grid-resistor-type controller in the secondary and a magnetic line starter in the primary winding is satisfactory. Shunt-wound motors require the standard-type starter with field control.

A more modern method of producing coated paper is the substitution of air pressure for the brushes in the brush-coating system. With the air-jet method greater speed of production can be attained, and more economical control can be maintained. The electrical system of such an installation is somewhat similar to the sectional drive of a modern paper machine. Accurate speed control is of primary importance and each part of the complete unit must be designed to fit into its proper place. In order to understand the real function of the electric equipment connected with air-jet coating, it is necessary to understand how the entire machine operates. First, the paper is unrolled into a trough of coating fluid and is conducted past a number of air jets across the width of the sheet. Air pressure is controlled by the speed at which the paper is traveling, that is, a reduction in speed increases the pressure and it is this air pressure that spreads the coating in a uniform manner. Its action is similar to that of a "doctor blade" on a paper machine; it removes the surplus coating and controls the finished thickness of the sheet. Both the speed of the paper and the air pressure can be regulated independently in order to get a varied thickness of coating. After the coating has been deposited, the paper is carried into a dryer which has a regulated temperature, then to a rewinder, and again is made up into rolls. This process requires a motor generator set for supplying armature current for the various shunt-wound d-c motors which drive several sections of the machine. A separate generator connected to the same drive motor as the armature current generator is used for field control of the section motors, each of which is excited separately and shunt-wound to operate on 250 volts direct current. The rollers in the vats, the dryer, and the rewinder press all must operate at the same speed. The rewinder press takes the paper from the dryer and a slack loop is maintained between the dryer and the press. The slack loop can be maintained by means of a photoelectric device or mechanically operated rheostat. The rewinder speed is slightly higher than the press to provide the desired tension and is controlled by a tension device installed between the press and rewinder. In operation, the speed is determined by the armature generator voltage. A master rheostat for each generator is located at the rewinder or dry end of the machine so that the operator can change to any speed required, and the draw between sections is controlled by means of manual rheostats which are located at suitable places along the length of the machine.

The motor generator set consists of a standard squirrel-cage induction motor and two compound wound generators which are compounded to maintain constant voltage with sudden change of load. Coating sections require a small d-c motor of about 5 horsepower while the dryer section needs about 20 horsepower (the press has a 10-horsepower motor while the rewinder usually uses a 20-horsepower motor).

CONDITIONER

Because large portions of the output of a fine paper mill are used by the printing trade, it is essential that the finished paper be suitable for use in printing presses. When paper first comes off the paper making machine it usually varies in moisture content across the width of the sheet. In a very short time the paper will dry out

or absorb additional moisture to such an extent as to cause the sheet to warp or develop tension, which will make it difficult for satisfactory secondary processing. The conditioner was developed to add moisture under such conditions in order to make the paper lie flat, and thus facilitate much better printing operations.

Paper is unrolled into the conditioner chamber and threaded through the various compartments. After passing through the moisture-laden atmosphere of the hot and cold compartments, the paper is rerolled. An extensive range of grades of paper requires different amounts of applied moisture, and a wide range of speeds is necessary to obtain the desired results. A squirrel-cage induction motor with a slip clutch can be used to drive the paper through the conditioner but a wound-rotor motor with a liquid controller has given the best results. Paper can be threaded through the machine without difficulty and smooth acceleration with stepless control gives any chosen speed.

STATIC ELIMINATORS

When paper is subjected to high pressure at top speeds, a heavy charge of static electricity is left in the sheet. A high-voltage a-c static neutralizer is used to remove or neutralize the static. This method has proved quite successful on supercalenders, but very unsatisfactory results have been obtained on cutters and paper machines. Some improvement is required in this field.

ELECTRIC TRUCKS AND TOW MOTORS

Material handling is a major problem in any finishing room and the electric lift truck and tow motor are an essential component of the equipment necessary for routing and shipping of paper. As paper mill operation is a 24-hour-a-day job, many of the electric trucks get very little rest, and a well-organized battery maintenance system is required. It has been found that at least five batteries are required for every two trucks on a 24-hour basis. Very little, if any, difference has been noted in the over-all efficiency and cost between the alkaline- and acid-type batteries in the handling of pulp and paper.

LIGHTING

The modern trend in lighting has been toward the fluorescent unit which has proved both popular and economical, particularly where power cost is high. In cutting, trimming, supercalendering, and other machine operations, fluorescent lighting has been adopted with a great deal of approval. Hand operations, such as sorting, counting, and inspection, have been a more difficult problem. In order to detect the many flows which are produced during the various processes of finishing, it is necessary to use a type of light which will cast shadows on the defects in the paper. Fluorescent lighting will not develop the desired shadow or show up such faults as fuzz, cockles (wrinkles), and stamps (low opacity spots). Fuzz can be detected by fluorescent light with the aid of a magnifying glass, if the light is directed at a proper angle. For color, matching fluorescent lighting is being used with exceptionally good results.

In conclusion it must be kept in mind that most of the fine paper mills are old established concerns and much of the equipment, although adequate, is far from modern. As the majority of fancy finishing room machinery can be driven by relatively small motors, it would appear that this would be an excellent application for electronic drives. On larger units the wound-rotor induction motor does an excellent job, and where close automatic speed control is desired the liquid controller can be utilized. There are now in operation two paper making machines with standard wound-rotor motor drives. The speed regulation is less than half of one per cent and is accomplished by means of an electronic-controlled liquid rheostat.

Conditions indicate a definite field for development in finishing room electric equipment, and electronics should find many applications.

Transformer for Bonneville

This 50,000-kva transformer destined for the Snokomish substation of the Bonneville Power Administration near Everett, Wash., is the largest single-phase transformer ever to be built by the Westinghouse Electric Corporation

Electrical Maintenance in a Newsprint Mill

JOHN EYTON
MEMBER AIEE

A general outline of the electric apparatus to be found in a newsprint mill, from the point-of-view of an electrical engineer in charge of maintenance, indicates what equipment has to be maintained, its choice, and certain requirements for its maintenance. The importance of efficient electrical maintenance is evident from the results that can be obtained provided the proper methods are followed.

ELECTRICAL maintenance in a newsprint mill depends on the type of apparatus installed, the systems of distribution used, the facilities provided for their upkeep, and their proper use. By the proper selection and use of these, electrical maintenance will be highly efficient and profitable.

Installations found in most mills today are far from ideal. This is because of the lack of importance attached to electrical services in the past. The fact that these services have grown to a point of major importance in the industry is becoming more apparent, and careful consideration should be given to all future plannings of electric installations.

In this article, a high-speed 2-machine mill is considered, assuming that power is delivered at a high voltage and that additional power is generated on steam turbine units. An outline and comments on some of the apparatus, distribution, and maintenance facilities in such a mill is presented in the following paragraphs from the viewpoint of an engineer in charge of electrical maintenance.

SUBSTATION

Outside equipment of a substation consists of

1. High-voltage structure.
2. Switching.
3. Lightning arresters.
4. Step-down transformers.
5. Secondary transformers for local load center.

Disconnect switches should be gang-operated and any main piece of apparatus easily isolable. There should be at least two similar main banks of transformers, each comprised of three single-phase units. The low-voltage sides of these banks should feed directly to two separate indoor main 4,000-volt station busses.

Secondary transformers for 550-volt power requirements and 115/230-volt lighting system in the vicinity, or within a radius of 400 feet, also should be mounted outside, with low-voltage sides connected to indoor secondary busses. At least one spare transformer of each size should be provided, in the event of failure on one unit. Transformers should be mounted on rails to enable easy transfer. Transformers, as well as oil breakers, should be connected to pipe lines so that oil can be dumped, replenished, or recirculated. Transformers of the self-cooled type would be preferable in northern mills.

The substation building houses the following equipment:

1. Station and secondary bus structure.
2. Switching.
3. Control and metering panels.
4. Control battery and charger.
5. Motor generator sets for grinder motor excitation.
6. Telephone and signal systems.
7. Oil storage tanks and purifier.
8. Repair bay.
9. Ventilation, heating, and lighting.

Two main station busses should be arranged on the same horizontal plane, and all main feeder circuit breakers fed through double-throw disconnect switches, so that they may be connected to either bus. Adequate spacing should be allowed to permit work on either bus when the other bus is energized. Barriers with electric interlocks should be placed in front of each set of disconnects, so that they cannot be *opened* with the associated oil switches *closed*. A channel bus would be recommended where heavy current carrying capacities are required.

Control and relay panels should be arranged back to back, with an open pit between for interconnecting control cables. Controls and indicating meters should be on panels facing front and relays and watthour-meters on the rear. Front panels should be arranged in such a fashion that they all can be observed from a central operator's desk. The controls for all switches, grinder exciter motor generator sets, and control battery chargers, should be on panels in the control room.

The control battery should be large enough to supply emergency lighting to stragetic points in the mill for at least an hour without jeopardizing reliability of control for necessary switching at the end of that time.

Individual motor generator sets for grinder motor excitation, and associated rheostats, field switches, and similar equipment should be installed in the substation. The control room in the substation should be the central intercommunication point for the mill, and should con-

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tain an automatic telephone exchange with code-call. Time signals and fire alarms also should be operated from the substation.

Two oil storage tanks should be provided for emptying at least two of the largest transformers. This would allow the complete emptying of oil from one transformer; oil then could be purified and transferred to the other tank, while repairs are made on the emptied transformer. To prevent increasing acidity and consequent sludging, it is recommended that an activated earth purifier be used for treating insulating oil, rather than just a blotter press or centrifuge.

A repair bay, with necessary work bench and hoisting facilities, and large enough to dismantle the largest transformer, should be provided. Front and back of switchboards, all bus work, and so forth, should be well-illuminated.

STEAM PLANT AND STEAM TURBINE UNITS

The steam plant would include

1. Coal conveyers, hoists, crushers, pulverizers, feeds, and fans.
2. Filters, pumps.
3. Lighting.

All motors subjected to coal dust, as in a pulverized installation, should be totally enclosed self-cooled or forced ventilated. Filter and pump motors, which are usually in an adjoining room, could be standard protected type.

Lighting should be accomplished by maximum use of wall angle-reflectors, and the avoidance of high ceiling fixtures which are difficult to clean. Special spotlights for gauges should be used with air jets to keep lens clean.

Steam turbine units would comprise

1. Turbine and gear reduction unit.
2. Synchronous motor or alternator.
3. D-c generators.
4. Necessary switching.

A steam turbine unit should be supplied for each paper machine, designed to discharge 75 per cent of steam requirements for drying paper, and at the same time generate sufficient power to drive the machine and some of its auxiliaries. The synchronous motor or alternator normally would be driven as a generating unit with sufficient load applied to give a proper steam balance. In the event of trouble on the turbine, the synchronous motor would be uncoupled from the turbine gear unit and used to drive the d-c generators for the paper machine drive.

Switching for the synchronous motor or alternator should be arranged so that when the unit is generating, it feeds a separate bus to which suitable blocks of load can be connected or disconnected, by the use of double-throw disconnect switches, to or from mill feeder bus. When the unit is used as a motor it would be operated off mill bus. Suitable relaying and switching should be arranged to enable the alternator to feed back into mill bus, so that essential services (lighting and boiler house auxiliaries) may be maintained in case of a complete failure of "outside" power supply.

WOOD ROOM AND WOODYARD EQUIPMENT

This equipment includes

1. Outside conveyers and reclaimers.
2. Drum and knife barkers, "woodpeckers," and the like.
3. Inside conveyers.
4. Lighting and heating.

A load center should be used to step mill bus feeder voltage down to 550 volts for all motors and 115/230 volts for the lighting system. Wound-rotor standard protected-type motors should be used on all long chain and cable conveyers, jack ladders or stacker, drum barkers, and chippers.

Squirrel-cage standard protected-type motors should be used on relatively short or small chain conveyers, all belt conveyers, belt bucket elevators, splitters, screens, rechippers, and heating fans. Squirrel-cage totally enclosed motors should be used on rossers, woodpeckers, and sawdust blowers.

The electrically operated crawler crane for wood reclaiming should be fed with trailer cable, with a "lead-in" on the swing-boom mounted on top of the cab and pivoted over the kingpin axis. Power plug receptacles with ground connections should be located conveniently in the woodyard for the operation of the electrically operated crane, moveable conveyers, and the stacker.

Open wiring is recommended for all outside lighting, preferably on angle-iron supports along the conveyers. General lighting of the stacking area should be by floodlights, mounted on 30-foot platforms at front, back, and sides of piles. Underground service cables should be run to these lighting towers on which power receptacles also could be located.

GROUNDWOOD MILL EQUIPMENT

This equipment consists of

1. Grinders and load regulating equipment.
2. Conveyers.
3. Fans.
4. Hoists.

As roughly 75 per cent of mill power is consumed in the groundwood mill, the substation should be as close as possible to this department.

Here, 4,000-volt synchronous grinder motors should be mounted over the openings in a ventilating tunnel, arranged with suitable baffles to conduct filtered air, from fans, to each motor. Signal pedestals with emergency "stops" should be located near each motor for notifying the substation operator to stop or start the unit, or to stop when an emergency arises. Load regulating units, with graphic wattmeters on motor circuits, should be installed for each unit; these should be in the

grinder room and the grinder operator should be able to vary the load up or down on any or all units. Load to be carried would depend on grinding requirements, but also should be kept within certain limits to be indicated by peak load signals from substation.

Block conveyer and fan motors in relatively clean locations should be standard protected type. Motors in damp or particularly dirty locations, and on crane and hoists, should be totally enclosed. Crane and hoists for handling stones and grinder parts should be electrically operated and so arranged on a system of rails that all heavy parts can be removed safely and quickly.

SULPHITE MILL EQUIPMENT

Sulphite mill equipment includes

1. Pumps.
2. Elevators and conveyers.
3. Fans and lighting.
4. Conduit.

All motors in the sulphite plant that are exposed to moisture and acid fumes should be totally enclosed; this would include elevator motors. Lighting with wall or column angle-reflectors is preferable to high ceiling fixtures, or ceiling units in "burner" room. Fixtures exposed to such hazards as moisture, acid fumes, and sulphur dust, should be vaporproof. Conduits should be protected against moisture and weak acids.

SCREEN ROOM EQUIPMENT

In this category are

1. Pumps, agitators, thickeners, screens, shredders, and refiners.
2. Tailings conveyers.
3. Ventilating fans and lighting.

Motors above 200 horsepower should be operated on 4,000 volts, all others on 550 volts, connected to distribution racks fed directly from substation main and secondary busses. Motors all should be standard protected type, unless in a very damp or dirty location, where totally enclosed units are recommended.

Standard ceiling and wall reflectors should be used for general lighting, but vaporproof fixtures, made easily accessible, should be provided for illuminating the interior of stock chests.

PAPER MILL EQUIPMENT

In the paper mill are

1. Pumps, screens, agitators, broke beaters, and compressors.
2. Paper machine drives and controls.
3. Hoists and cranes.
4. Fans and lighting.

The paper mill should be the location of a "load center" for 550-volt power and 115/230-volt lighting systems within a radius of 400 feet. This center would be fed by 4,000-volt feeders directly from the main station bus. All a-c motors above 200 horsepower should be operated on 4,000 volts, and lower ratings on 550 volts.

All motors should be standard protected type or should be provided with drip covers, with the exception of units in damp locations and "drive" motors. The former should be totally enclosed, self-cooled, and the drive motors enclosed, forced ventilated. Synchronous motors should be used on large vacuum pumps and air compressors, direct connected.

Electric sectional paper machine drives should be installed, with "wet-end" section controls grouped in the center aisle near "wet-end," and "dry-end" controls similarly at their end, along with large indicating tachometers for each machine. Main control boards and equipment should be housed in a well-ventilated enclosure in the basement, which also would house the "drive" generators and ventilating fans. Air which is passed through fan for motor cooling purposes should be filtered. Crane and hoist motors should be totally enclosed.

Good ceiling lighting should be provided over "wet" and "dry-end" of paper machines, with adequate lighting under dryer hoods and over drives and the center of the room for ordinary repairs and cleaning. Vaporproof fixtures should be installed at the back of dryer frames. The protecting globe is necessary to avoid fire hazard resulting from paper "broke" and oil which otherwise would come in contact with the bare lamp. Fluorescent lighting will be found desirable on calender stacks, reel, and winders.

FINISHING AND SHIPPING ROOM EQUIPMENT

This equipment comprises

1. Rewinder, wrapper cutters, and core machines.
2. Headers.
3. Elevators, delevators, and conveyers.
4. Electric trucks and charging equipment.

Standard protected-type motors should be used on all drives, except on core saws and elevators, which should be totally enclosed. Headers for newsprint rolls should be heated electrically and controlled thermostatically.

D-c motors on electrically operated trucks should be totally enclosed and readily accessible. Battery charging equipment and charging racks should be enclosed in special room into which trucks can be driven for a battery change.

REPAIR SHOP EQUIPMENT

In the repair shop are found

1. Machine tools and grinders.
2. Woodworking machines.
3. Forge blowers.
4. Welding machines and portable tools.
5. Hoists and cranes.
6. Lighting.

All motors on machine tools should be standard pro-

tected type. Motors on woodworking tools and grinders should be totally enclosed type. Forge blower motors, if in a dusty location, should be totally enclosed.

Welding machines should be portable and of at least 300 amperes capacity. Hoists and cranes should be operated electrically and should have totally enclosed motors. Lighting over the whole working floor should be good with localized lighting units over the working areas on lathes, shapers, planers, milling machines, grinders, drill presses, and other equipment.

OFFICE AND MISCELLANEOUS EQUIPMENT

This equipment includes

1. Ventilating fans.
2. Signal systems.
3. Calculating machines, and so forth.
4. Lighting.

A central air conditioning unit should be supplied for the main offices. Suitable outlets and duct work should be provided for the installation of necessary telephones, signal systems, and plugging in of the electrically operated calculating machines that may be used in several locations. Lighting over all desks should be from ceiling units.

SYSTEMS OF DISTRIBUTION

Distribution systems comprise

1. Primary feeders.
2. Load centers and secondary feeders.
3. Distribution points and switches.
4. Branch circuits.
5. Control cables.

As many cables as possible should be lead-covered steel-tape-armored, and should run on cable supports in a tunnel or in channel-iron runways.

Primary feeders at 4,000 volts should feed all motors over 200 horsepower, and also the various load centers. Load centers should be placed so that all apparatus which they serve is within a radius of 400 feet. Secondary feeders from these centers should go to the necessary distribution points. Distribution points should be the center of all switches and circuits required for a certain area. These switches should be in a separate room or enclosure, automatically controlled from push button stations situated close to the apparatus with which they, respectively, are connected.

The branch circuits from distribution points, also all control circuits, should be run in conduit. Control and main cables to various sections of paper machine drives should be run in lead steel-armored cables on channel-iron runways.

REQUISITES FOR MAINTENANCE

For proper maintenance of equipment the following are necessary:

1. Spares.
2. Standardization of equipment.
3. Shop and office space.
4. Tools and instruments.
5. Competent staff.

It is very important that spares be on hand for all electric equipment vital to production. In order to reduce the number of spare parts to a minimum, the types and sizes of motors, starters, switches, wires, cables, conduits, fittings, lamps, and the like, should be standardized to the utmost.

A large well-lighted and ventilated shop with necessary benches, bake oven, and spraying booth should be provided. The electrical office should adjoin the shop and should be the center of all activities such as supervision, planning, and records.

Necessary large hand tools, lubricating equipment, hoisting tackle, winding tools, lathe, press, surfacer, pipe cutting and threading tools, vises, drill press, grinder, spray guns, brasing or soldering transformers, and wire or cable pulling equipment should be provided. A test panel board also should be provided in the shop with necessary voltages required.

For testing and making records of repaired or installed equipment, a good selection of instruments should be provided. These should include: graphic polyphase wattmeter, voltmeter, and ammeter; indicating polyphase wattmeter; voltmeters of various a-c and d-c scales; ammeters of various a-c and d-c scales; and necessary portable instrument transformers and shunts. Recording and indicating tachometers also should be provided.

In order properly to maintain and plan improvements to the electric equipment in a newsprint mill, the services of a skilled superintendent and competent staff of experienced electricians are essential. Any helpers who are taken into the electrical department should be picked carefully, should be trained, and should be encouraged to take electrical courses which will give them some technical knowledge.

In the foregoing, a general outline has been given of electric apparatus which is to be found in a newsprint mill. It has been the object of this article to point out what equipment has to be maintained, its choice, and certain things that are required for the maintenance of this equipment.

Provided the proper methods are followed, records of equipment kept, and performances of apparatus checked, the following results should be obtained:

1. Fewer work stoppages.
2. Maintained efficiencies.
3. Fewer replacements.
4. Longer useful life of equipment.
5. Reduced time on repairs and overhauls.
6. Indication of improvements required.
7. Profitable changes and developments.

With such results possible it seems evident that efficient electrical maintenance in a newsprint mill should be the aim of present and future planning.

A-C Motors for Paper Mill Chippers

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Chipper drive is one of the most exacting applications to which motors are applied. The size of the motor is determined primarily by the high peak loads which occur intermittently when large logs are fed. Motors for this application must be made mechanically stronger than standard to withstand the shock loads and vibration imposed by the chipper.

THE CHIPPER is one of the most important pieces of equipment used in the manufacture of chemical wood pulp. It cuts the barked logs into chips of suitable size to be treated chemically in the digesters. Chippers are built in a wide range of diameters to handle the various sizes of logs, which vary from 8 to 24 inches in diameter, and usually are cut into 4- or 5-foot lengths in Canadian, eastern, southern, and midwestern mills, but are handled in 30-foot lengths with diameters up to 42 inches or more in mills in the west.

In construction, a chipper consists of a heavy cast iron or steel disk which has a number of slots in it. A knife is bolted in each slot with its cutting edge radial and extending close to the outside of the disk which is mounted on a shaft carried in two bearings (Figure 1). The logs are fed through a spout that is inclined so that the knives cut across the grain at an angle of about 45 degrees. A heavy anvil at the lower end of the spout takes the shock of the cut. The knives are adjusted to produce chips which are five-eighths to seven-eighths of an inch long, measured parallel to the grain of the wood. As they are cut, the chips pass through the slots in the disk to the rear of the chipper, where they are broken up further by breaker bars attached to the rear face of the disk. As shown in Figure 2, a cover confines the flying chips, and they are discharged into a conveyer or blower system which takes them to the next step in the process.

The capacity of a chipper is given in stacked cords per hour, and its capacity varies as the square of the diameter of the spout, and directly as the speed and the number of knives. The diameter of the spout is usually from 20 per cent to 25 per cent of the diameter of the disk. The maximum stress in the disk from centrifugal force limits the maximum operating speed. The horsepower-hour requirements for various species of wood are given in Table I. These values were obtained from numerous tests of chippers in normal production, and were checked by tests made under laboratory conditions.

SELECTING A CHIPPER

The chipper size usually is selected so that all but the very largest logs will go into the spout without having to be split or sawed into cants. The chipper also must be designed so that it will maintain the required rate of production with a run of average size logs. The log which gives the lowest production rate is one just over half of the spout diameter, as this is the smallest log that must be fed one at a time. The production rate of the chipper ordinarily is adjusted by choosing the proper number of knives, and chippers are built with 2, 3, 4, 6, 8, 10, or 12 knives to obtain the required production rate with the average size of log. It is possible to adjust the production by changing the speed, but this is not often done to any great extent as it is usually uneconomical to operate a chipper much below its maximum permissible speed.

In estimating the chipper capacity to suit the mill capacity, it is usual to allow two cords of wood for each ton of finished plup. If the chipper is not operated during all shifts, its capacity must be increased accordingly, and it is desirable to have some excess capacity to allow for shutdown time to change knives and for other interruptions.

DETERMINING THE MOTOR RATING

In order to apply a motor to a chipper, it is first necessary to determine the maximum horsepower which the motor must develop. This maximum peak load occurs when the largest log is fed, and the motor must be able to deliver the torque corresponding to this maximum horsepower. It is obviously possible to choose a number of combinations of rating and pull-out torque which will give the same maximum horsepower, but, in general, it is most satisfactory and economical to use a motor with 250 per cent pull-out torque. With 250 per cent pull-out torque, the horsepower rating of the motor will be the maximum horsepower as determined in the foregoing for the largest log divided by 2.5, and the result adjusted to the next higher standard rating. If the power supply to the motor is such that the voltage drops when peak loads occur, the pull-out torque will be decreased when these dips occur, and the rating should be adjusted accordingly. The pull-out torque of a synchronous motor varies directly as the voltage, while the pull-out torque of an induction motor varies as the square of the voltage.

The motor horsepower rating ordinarily is based en-

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Table I. Energy Requirements of Chippers Cutting 3/4-Inch Chips From Various Species of Wood

Species of Wood	Horsepower-Hours Per Stacked Cord	Per Cent of Hemlock
Hemlock	7	100
Yellow pine	6.1	87.1
Gum wood and poplar	10	142.8
Oak and other hard woods	12.3	175.7

tirely on the maximum power required by the largest log. If the average logs are larger than the optimum log diameter, the capacity of the chipper must be reduced by intermittent feeding to avoid overheating the motor. If this reduction in rate of production does not permit the requirements of the mill to be met, the rating of the motor must be increased to obtain greater thermal capacity in the motor. If this is done, the pull-out torque in per cent can be reduced to maintain the same maximum horsepower. If a synchronous motor is used, the high pull-out torque required in a chipper motor will be obtained most economically with an 80 per cent power factor motor.

Typical characteristics of a number of representative chippers are given in Table II.

MOTOR STARTING REQUIREMENTS

The chipper is started empty, and the motor needs to develop only sufficient starting torque to overcome the friction of the bearings. Usually, 40 per cent torque is sufficient to start under the worst conditions which occur after an extended shutdown period in cold weather. If reduced-voltage starting is used, the full-voltage torque must be increased so that the required torque of 40 per cent is obtained at the reduced voltage. Once the motor starts to rotate, the torque drops to a very low value represented by the running friction of the bearings and the windage of the disk. In spite of the low torque requirements, it has been the practice in the past to specify 80 per cent pull-in torque or more for synchronous motors. Such high torque is not necessary for the motor to be able to pull the chipper into step, but it does insure a high average torque during acceleration and a reasonably short starting time. If a limited power system makes it desirable to hold the starting inrush of the motor to the lowest possible value, it may be better to allow a longer starting time to obtain the lower starting current which the manufacturer can guarantee with 40 per cent or 50 per cent pull-in torque.

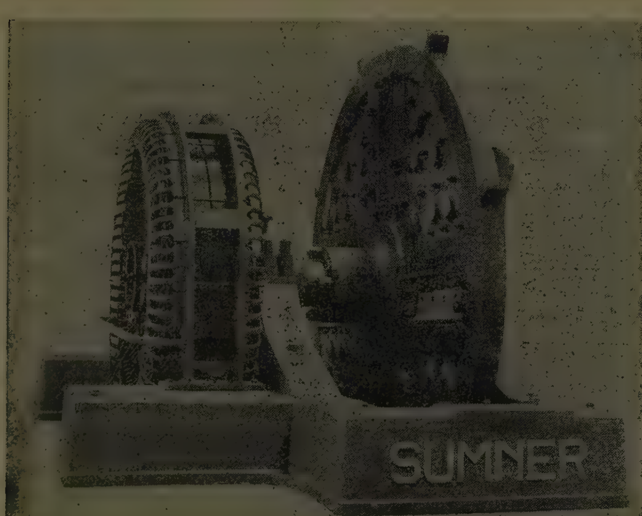

Figure 1. Cover removed from 110-inch 4-knife chipper showing construction of disk and overhung-engine-type synchronous motor drive

While accelerating the inertia of the chipper disk, an amount of heat is developed in the secondary or rotor windings which is equal to the stored kinetic energy of the rotating parts at full speed. In an induction motor with a wound rotor, this heat can be dissipated in an external resistor, but in squirrel-cage induction motors and synchronous motors, this heat must be absorbed by the motor rotor. The design of the starting winding becomes more difficult in the larger sizes. It is evident that the stored energy increases rapidly as the diameter of the disk increases, so that the ratio of the stored energy to be rated horsepower of the motor increases with disk diameter.

Special role construction is required to absorb the heat stored in the chipper disk and motor rotor. The bars in the pole face are about four times normal size, and in one machine are made of monel, an alloy which maintains its high strength at elevated temperature. All bars are of the same material and are proportioned to come to approximately the same total temperature to prevent excessive stresses from unequal thermal expansion of the bars. A flexible joint in the short-circuiting end ring between each pole prevents thermal expansion of the ring from impressing extra stresses in a radial direction. When special designs similar to this one are used, synchronous motors can accelerate the inertia of the largest chippers without adverse effects. Synchronous motors seldom are belted to chippers except in the smallest sizes because a high speed motor for belted service is smaller physically than a direct-connected motor with its lower speed, and is less able to absorb the heat developed during acceleration.

CHOOSING THE TYPE OF MOTOR

The choice between an induction motor and a synchronous motor, and the choice of the mechanical arrangement of the drive, will depend on the size of the chipper. To drive the smallest chippers, up to about 84-inch diameter, belted induction motors are used most commonly, although a few belted synchronous motors have been installed. Belting the motor permits it to operate at a speed considerably higher than the chipper speed, with some saving in cost. A high-speed induction motor has better power factor and efficiency than a

direct-connected motor. If the belted motor is put on a separate foundation from the chipper, it is protected to some extent from the vibration produced by the chipper, and standard mechanical construction can be used.

From 84- up to 110-inch chippers, either belted induction motors or engine-type synchronous motors are used. Synchronous motors may be overhung on an extension of the chipper shaft, or an outboard bearing may be supplied as part of the chipper. By mounting the motor on the chipper shaft, considerable space is saved and belt maintenance is avoided. Unlike induction motors, synchronous motors have good efficiency at the low speeds required for direct-connected motors. Motors rated 80 per cent power factor will help to correct the average power factor of the mill. Some engine-type motors are designed to permit a limited amount of axial movement of the rotor as required for the adjustment of some makes of chippers.

Synchronous motor drive has an advantage in that the production of chips holds up to a maximum because the speed remains constant, regardless of load. On the other hand, none of the stored energy in the chipper disk can be used to carry part of the peak loads. The high inertia does carry the motor through the very high momentary peaks that occur as each knife makes its cut. The energy required for one full cut is never more than 1.4 per cent of the stored energy. The inertia smooths out the torque peaks so that the effect on the motor is about the same as if the actual torque is replaced by a constant torque equal to the average value of the actual torque. A synchronous motor must carry the entire load represented by the average torque required by the largest log. An engine-type motor mounted on the chipper shaft always must be of special mechanical construction to withstand the severe vibration typical of this application.

Induction motors also are used quite commonly to drive 84- to 110-inch chippers. They almost always are belted to take advantage of the better performance of high-speed motors. Standard mechanical construction is usually suitable for belted motors mounted on a separate foundation. If an induction motor is used, it is possible to use some of the energy in the chipper disk to reduce the power peaks to be carried by the motor, and consequently reduce the maximum current drawn from the line. The comparative characteristics of three types of motors are given in Table III.

Because of its reduced efficiency and lower rate of production, a high-slip motor should be used only in applications which have a power supply so limited that the higher kilowatt and kilovolt-ampere loads imposed by a synchronous motor or a normal-slip induction motor cannot be tolerated. It is not ordinarily possible to help the production rate of a chipper driven by a high-slip motor by using a belt ratio to give a higher speed at no load than is used with a normal-slip motor, as the chipper then will exceed its permissible speed at no load. A squirrel-cage motor can be built with high slip in small sizes, but above 150 horsepower it is difficult to dissipate the rotor losses if the slip required is more than three or four per cent. If higher slip is required, it is necessary to use a wound-rotor motor with a permanent external resistor inserted in the rotor circuit.

Very large chippers with disk diameters above 110 inches to 175 inches usually are driven by synchronous motors coupled through flexible couplings. These large chippers are suitable for the large logs found in the Northwest. A log 30 feet long has a volume equal to 480 full cuts with 3/4-inch chips. A 42-inch log which could be fed to a 175-inch chipper requires 72,400 horsepower-seconds to chip the log. The stored energy of the disk is only 35,700 horsepower-seconds, so it is evident that the inertia will not carry the load, and the motor must carry the peak load before the end of the log is reached, even if a high-slip induction motor is used. A synchronous motor will carry the peak load with less current at better power factor than an induction motor, so it is favored for this application.

MECHANICAL FEATURES OF SYNCHRONOUS MOTORS

When one of the chipper knives enters the log, a shock is imposed on the disk and the anvil and transmitted to the shaft and foundation. Some of the resulting vibration is transferred unavoidably to the motor. Engine-type motors which have their rotors mounted directly on the chipper shaft and their stators mounted on the base of the chipper are subjected to a large portion of the vibration. Even motors coupled through flexible couplings are subjected to severe vibration and must be made much stronger than for normal applications, and consequently cost more than standard motors.

To withstand the vibration, special construction is

Figure 2. Chipper with cover in place showing spout through which logs are fed

used. In the stator, the main frame rings are made thicker and larger in diameter than standard. A heavy cover plate is welded to them and is extended to the ends of the feet, both above and below the base. Additional bracing members also are used to stiffen the frame against axial movement, and a large number of heavy bolts are used to fasten the frame to the bedplate. The rotor is of equally strong construction, with a heavy 1-piece forged-steel spider. This construction often is used for motors rated 1,000 horsepower and larger, although cast steel or fabricated steel spiders are adequate for the service. In the smaller sizes, the spider usually is fabricated of heavy steel plate, with the rim, hub, and web being made thicker than normal, and with additional bracing members added to strengthen the structure against axial forces.

Coupled motors are made with very heavy bedplates, and at least twice as many foundation bolts of increased size are used as in standard machines. Motors can be supplied with either sleeve bearings or antifriction bearings. Sleeve bearings can be replaced without dis-assembling the motor, can be rebabitted by the user, and have less loss during normal operation than anti-friction bearings, although they require more starting torque. The chippers usually use antifriction bearings which must be very large to support the weight of the disk. If specified, motor bearings which are interchange-able with the chipper bearings can be supplied at an in-crease in cost.

With each knife cut, a torsional shock is imposed on the rotating parts. The torsional system formed by the chipper disk, the motor rotor, and the connecting shaft should be checked to make sure that it is not resonant at one of the imposed frequencies. The knives are not necessarily uniform, and this can give impressed frequencies lower than the principal knife frequency which, in cycles per minute, is the motor speed in revolutions per minute multiplied by the number of knives. One dull knife will impose a force once a revolution to give the lowest possible frequency. The torsional system actually will have two critical frequencies because the electric forces between the rotor and stator of the motor act like a spring, giving rise to a natural frequency much lower than the one with a node in the connecting shaft. In most applications, this lower critical frequency will be safely below the lowest forced frequency produced by one dull knife.

Other adverse conditions to which motors driving chippers are subjected are excessive moisture and the fine sawdust which escapes from the chipper housing and is carried into the motor. Some operators use enclosed motors and ventilate them with clean air. This protects the motor, but requires duct work and a motor-driven fan to circulate the ventilating air. If the motors are not completely enclosed to exclude the dirt entirely, it is usually better to make them as open as possible so that the dirt can be cleaned out more easily. End bells to provide mechanical protection to the windings should be made of steel straps which do not trap the dirt and permit it to be blown out easily. Some makes of chippers require special protecting covers for engine-type driving motors mounted very close to the chipper housing.

The motor windings must have the best possible insulation and treatments to withstand dirt and moisture. The stator windings must be braced more securely than usually is done for full-voltage starting, as the coils must be held securely against the stresses imposed by heavy starting duty and loads that flucutuate widely and often approach the pull-out point.

CONTROL REQUIREMENTS

The requirements for the control for a chipper motor are relatively simple, as the only operating functions required are to start and stop the motor, and to provide adequate protection against abnormal conditions. In stopping the motor, it frequently is considered desirable to provide dynamic braking to reduce the stopping time. Without dynamic braking, the stopping time is long because of the high inertia of the disk. Dynamic braking reduces the outage time required to change knives, which may have to be done as often as every four hours to maintain productive capacity and chip quality.

Enclosed control is recommended for chipper installations. It must provide adequate overload protection and still permit uninterrupted operation within the

Table II. Characteristics of Typical Chippers

Disk Diam (In.)	Spout Diam (In.)	Speed (Rpm) *	WR² Disk (Lb-ft²)	Stored Energy (Hp-sec)	Cu In. Per Full Cut **	Energy Per Full Cut (Hp-sec) **†	Production Per Knife (Cords Per Hr) Peak **	Production Per Knife (Cords Per Hr) Cont **‡	Power Per Knife (Hp) Peak **†	Power Per Knife (Hp) Cont **†‡	Optimum Log Diam (in.) **‡
54	12	600	10,000	1,120	85	12.3	17.6	7.0	123	49	7.6
84	14	450	35,000	2,200	115	16.8	17.9	7.2	125	50	8.9
88	18	400	55,000	2,720	191	27.7	26.4	10.5	184	74	11.4
96	22	360	80,000	3,220	285	41.4	35.4	14.2	248	99	13.9
110	26	300	150,000	4,180	398	57.8	41.0	16.5	288	115	16.4
150	34	277	1,000,000	23,800	681	98.8	65.0	26.0	455	182	21.5
175	42	240	2,000,000	35,700	1,040	150.8	86.0	34.4	602	240	26.6

* Maximum permissible operating speed.
** Based on $^3/_4$-inch long chips and diameter of log equal to spout diameter.
† Based on hemlock wood requiring seven horsepower-hours per stacked cord.
‡ Based on motor with 250 per cent pull-out torque.

thermal capacity of the motor when it is subjected to intermittent peak loads. In addition to overload protection, controls for synchronous motors must provide protection against pulling out of step. Pull-out protection usually disconnects the motor from the power supply if the peak load torques exceed the maximum torque of the motor, and pull it out of synchronism. The motor cannot be resynchronized until the chipper has been unloaded. When short logs are being fed, it is possible to interlock the motor control with the log feed, and automatically unload the chipper when the motor pulls out of step by stopping the feed. The inertia of the disk will finish chipping the log that is already in the machine. Under these conditions, the control can be arranged to remove the field current and initiate the starting cycle after the motor pulls out, which will cause the motor to accelerate and synchronize again without a shutdown. A damper winding protective relay is another desirable feature to include in the control for synchronous motors. This relay is responsive to conditions which cause excessive heating of the pole-face starting winding, such as failure to start, and will trip the motor off the line before serious damage is done.

Table III. Motor Performance for 88-Inch 4-Knife Chipper

Hemlock Logs 18 Inches in Diameter, 4 Feet Long

	Motor A	Motor B	Motor C
Time to chip one log	2.4 seconds	3.34 seconds	4.7 seconds
Maximum power drawn from line	790 horsepower	750 horsepower	580 horsepower
Maximum current drawn from line (based on 2,300 volts)	164 amperes	186 amperes	138 amperes
Efficiency at peak load	93 per cent	87 per cent	73 per cent
Approximate average efficiency	93 per cent	89 per cent	79 per cent

Motor *A*—300-horsepower 2,300-volt synchronous motor with 250 per cent pull-ou torque.

Motor *B*—Similar to *A* except squirrel-cage induction motor with 2 per cent full-load slip.

Motor *C*—300-horsepower wound-rotor motor with 10 per cent full-load slip and 200 per cent pull-out torque.

Wound-rotor motors applied to chippers require special starting resistors with high thermal capacity. If permanent resistors are used to increase the full-load slip, they must be specified for continuous duty. The secondary control for a wound-rotor induction motor either may be operated manually or operated magnetically, depending on the size of the motor and the equipment layout. Automatic control is recommended for the primary circuit of all types of motors, with electrically operated main circuit switches and a control station located at a convenient point.

The capacity of the mill power distribution system will determine whether full-voltage starting can be used, or if reduced-voltage starting is required for either synchronous or squirrel-cage induction motors. If reduced-voltage starting is used, the starting torque must be specified high enough so that the actual torque at the starting voltage will not be less than about 40 per cent to give some margin above the static friction. With very limited systems which require the starting kilovolt-amperes to be held to a minimum, a wound-rotor induction motor should be applied.

In controls for synchronous motors, it is possible to provide automatic means to adjust the field current to suit the load. By the use of this feature, the peak load that the motor will carry can be increased by at least 25 per cent. When low starting current is wanted, a smaller motor with lower starting kilovolt-amperes sometimes can be used, and the required peak torque obtained by automatically increasing the field current during the peak loads.

All controls must have the interrupting capacity to open the maximum fault currents at the motor leads. Normal interrupting capacity of standard industrial control is ten times the motor rating, but higher interrupting capacity can be provided to meet the actual circuit conditions. Interrupting capacities up to 50,000 kva at either 2,300 or 4,160 volts can be furnished in standard industrial controls which use circuit breakers. These interrupting capacities can be increased to 150,000 kva at 2,300 volts or 250,000 kva at 4,160 volts by using current limiting fuses and contactors. For still higher interrupting capacities, heavy duty switchgear can be supplied to interrupt 500,000 kva at any voltage which may be used in pulp and paper mills.

New Radial Accelerator

A new machine now being built by the United States Navy will subject aircraft pilots and instruments to high accelerations, equivalent to those experienced when flying military aircraft. It will be considerably larger than machines now in use for this purpose.

Powered by an electric drive system developed by General Electric engineers, the new accelerator will provide radical accelerations up to 1,290 feet per second per second, or 40 times the acceleration of gravity. The rotating system will be driven directly by a vertical motor rated 4,000 horsepower and capable of developing a maximum torque of 1,700,000 pound-feet.

Acceleration patterns of aircraft in flight maneuvers will be simulated by the drive, which utilizes an amplidyne exciter in combination with an electronic control system, which, in turn, will be responsive to a program control.

Emergency stopping will be accomplished by dynamic braking, the machine being brought to a final halt by pneumatically operated brakes.

Recent Developments in Relays

RELAYS which combine high speed and great uniformity of performance over long periods of time are required for some uses in the telephone plant. The relays described possess these qualities to an unusual degree. Detailed description is limited to two types, each typical of a generic family in which the principles involved apply to all.

These relays are based on the philosophy that a motor element (any device for conversion of electromagnetic to mechanical energy), which is efficient and magnetically and elastically stable and operates contacts sealed in a proper atmosphere free from dirt and film, will give reliable performance if the contact load is engineered to the capacity of the contact. The relays require no maintenance beyond unit replacement, for there is no possibility of a change in adjustment after assembly is completed.

In one form the contact is provided for by metal in solid form, while in the other a mercury film supported on solid metal surfaces provides the contacting medium. The mercury at the contacting surfaces is replenished continuously through a capillary path from a mercury reservoir below the contact.

Glass-Enclosed Reed Relay

W. B. ELLWOOD

STRUCTURE of the glass-enclosed reed relay is shown in longitudinal section in Figure 1. The relay comprises a coil and a magnetically operated switch enclosed in glass. The switch is used as the core of the coil which provides the operating magnetomotive force. A steel shield can is used to provide mechanical protection for the coil and switch, to reduce magnetic coupling between relays, and to increase the magnetic efficiency. Terminals are provided for the switch and coil on an octal base. This arrangement allows the relay to be easily connected in a circuit in the same manner as a vacuum tube.

The switch comprises a pair of magnetic reed springs of perminvar, mounted inside and in opposite ends of a glass tube. The planes of the reeds are parallel, the adjacent ends overlap and are separated by a small gap. On the distant ends one reed is welded to a stiff rod of 52 alloy, and the other is welded to a stiff tube of the same material. This tube is used for exhausting the air and filling the glass tube with hydrogen, and after these operations it is closed with solder. The 52 alloy has a coefficient of expansion approximately matching that of the glass and is used for anchoring the reeds rigidly in a vacuum-tight glass-to-metal seal. The ends of the reeds which serve as the contacting elements are gold-plated.

Both electrical insulation and the mechanical support for the reeds are provided by the glass envelope. This arrangement provides greater rigidity and economy of space as compared with structures in which the supporting frame and envelope are separate. The glass envelope serves also as container for the hydrogen gas atmosphere. Glass is the most stable and inert thermoplastic insulating material capable of forming a vacuum-tight seal.

The working magnetic gap is between the adjacent ends of the reeds and is located at the approximate center of the operating winding because this position gives the greatest magnetic efficiency. The glass tube and winding are held rigidly in place in the steel can by filling the voids with wax. Once the relay assembly is completed the mechanical and electrical adjustments cannot be changed.

PERFORMANCE

Relays of this type typically require an average current, just to operate, of approximately 4.3 milliamperes in a 2,500-ohm 19,000-turns coil. This corresponds to a magnetomotive force of about 80 ampere turns and a power dissipation in the coil of 46 milliwatts. The present process of manufacture produces switches that require operating currents which may differ individually as much as plus or minus 25 per cent from the aforementioned value.

The repetitive precision with which a given relay may be expected to operate is within one per cent of its minimum operating current. This precision is substantially independent of number of operations, ambient temperature, or position. It is also independent of frequency of operation at low frequencies. Operating currents much larger than the minimum have little effect other than heating the winding.

The contact load capacity is limited to one-half ampere instantaneous current with voltages up to 48 volts. Voltages and currents in excess of these values are likely to shorten the service life considerably.

At present no prediction can be made concerning the life expectancy of the contact under service conditions. However, a small group of test units, each closing and opening a practically noninductive circuit carrying one-half ampere at 48 volts at 60 closures per second, all have exceeded 100 million operations without failure.

Essential substance of a conference paper presented at a joint session of the AIEE Midwest general meeting and the National Electronics Conference, Chicago, Ill., November 4, 1947.

W. B. Ellwood is a member of the technical staff of Bell Telephone Laboratories, New York, N. Y.

Under other conditions failures have been distributed over a range of from 3 million to 1,000 million operations. In inductive or capacitive circuits provision must be made to limit the peak current through, and the rate of voltage rise across, the contact. In any case it is undesirable to exceed one-half ampere peak current, and in no case should the direct voltage across the open contact exceed 400 volts if the switch is to open the circuit. Loads exceeding 10 watts will shorten materially the contact life.

Operating time of one millisecond may be obtained with a variation of 0.3 millisecond from relay to relay. The repetitive stability of an individual relay is such that the operating time varies by only 0.1 millisecond under constant drive conditions. If the relay is operated repeatedly at a frequency of 100 cycles or more, the interval or contact pulse length may vary as much as 0.5 millisecond from the average, because of the interaction of the drive current frequency and the residual normal vibration frequencies of the free reeds, which may not have time to die out between operations. The fundamental frequency of the reeds is about 700 cycles.

The switch unit is a device with low electrostatic capacity between its terminals. In mountings other than those shown here, the inter-reed capacity is about one micromicrofarad in combination with high insulation resistance and low capacity to ground.

The contact resistance is extraordinarily stable and low. Normal new switches exhibit a resistance between 15 and 30 milliohms. Repetitive resistance measurements on individual switches made at low voltage, 1.5 volts 0.10 ampere, have been constant to one milliohm. Under some load conditions both the average and the dispersion of the resistance values may be somewhat higher.

MODIFICATIONS

In general, the problems involved in the manufacture of any multicontact form of switch construction have tended so far, to limit this relay to simple contact combinations rather than the multicombination forms of the conventional telephone relay. However, the switch has been made experimentally in various other forms than the simple make type shown. Some other arrangements have been constructed such as: a simple transfer (break-make or double throw combination), a magnetically biased break contact, simple round wire springs instead of flat reeds, a T-shaped polarized structure, and several simple make contacts in one glass envelope. These forms have not been developed to the same degree as the type shown.

The switch also may be operated by a permanent magnet adjacent to the switch. A special form of switch in which the glass envelope is shortened and one of the flexible reeds is replaced by a short rigid stub of magnetic alloy is suited particularly to precise operation with a small magnet at a clearance distance of about 1/32 inch between magnet and stub. It has been described in connection with a gauge for measurement of magnetic potentials.[1] This switch has been operated repetitively with a permanent magnet with a precision of plus or minus 0.002 inch in the relative position of magnet and switch. Once operated, the switch does not release until the magnetomotive force is reduced to a very low value corresponding to a clearance distance of about one-half inch. This same switch is capable of operation at nearly 1,000 pulses per second.

The switch unit with its small volume, low inter-reed capacity, stable low contact resistance, straight line arrangement of terminals, and high speed is suited especially for use as a switch element inside a coaxial cable. The switch is operated by a coil wound on the outside of the cable. Switches of this type have been used in the New York, N. Y., to Philadelphia, Pa., and the Minneapolis, Minn., to Stephens Point, Wis., coaxial cables. The switches allow duplicate facilities to be switched into the circuit without interfering with speech transmission.

High speed and exact operating current features of

Table I. Typical Glass-Enclosed Reed Relay Characteristics

Characteristic	Value
Operating power	46 milliwatts
Operating time	1 millisecond
Repetitive stability (at low operating rate)	1 per cent operating current (0.1 millisecond)
Space required	3 cubic inches
Contact resistance	30 milliohms
Maximum contact load capacity	25 watts
Contact life range	3 to 1,000 million operations depending on circuit conditions

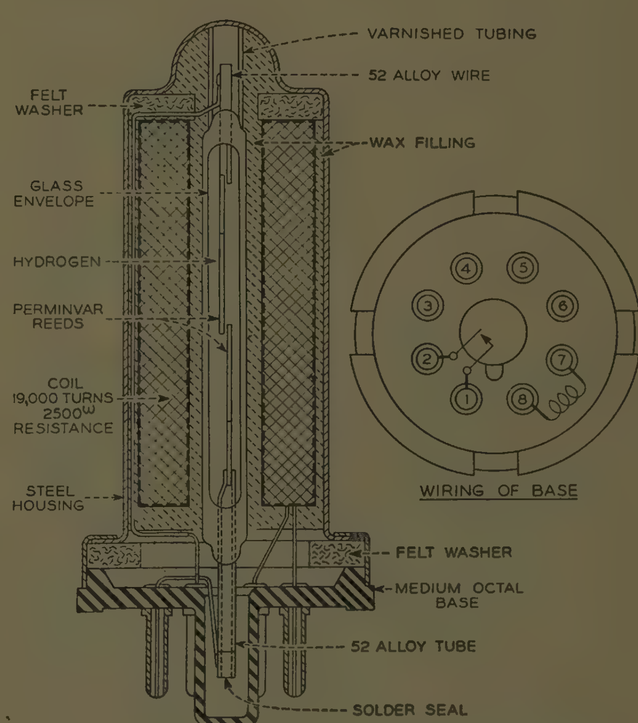

Figure 1. Longitudinal section of glass-enclosed reed relay

the relay make it suitable for use in some parts of voice current-controlled devices. The relay has been used experimentally in these devices. Accurate time characteristics of the relay make it especially suited to use as a high speed commutator. The sequential operation may be obtained mechanically by a motor-driven magnet, or electrically by suitable alternating currents generated by electronic means. It has been used successfully in a form of time division multiplex system.

The high grade contact performance of the relay makes it possible to use it as a commutator to rectify or invert exceedingly small voltages. Voltages of a few microvolts have been rectified synchronously in this manner.

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Mercury Contact Relays

J. T. L. BROWN　　C. E. POLLARD
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ELECTRIC contacts between solid metal surfaces tend to give trouble in a number of ways. They wear down, get dirty, stick by locking or welding, and chatter. It long has been recognized that all of these difficulties might be avoided by using mercury contact surfaces instead of solid metal. However, most designs of relays and switches employing mercury have tended to be slow in operation, ordinarily being based on the motion of a fairly large quantity of mercury by gravitational acceleration.

Active development work on mercury contact relays has been carried on in the Bell Telephone Laboratories, New York, N. Y., for a number of years. An outstanding result of this work has been the development of techniques for maintaining solid metal contact surfaces continuously wet with mercury by means of a capillary connection to a mercury reservoir below the contacts. This minimizes the amount of mercury which has to be put in motion for operation and permits the moving contacts to be carried by a light armature capable of high speed.

The original design, shown in Figure 2, comprises a single-pole double-throw magnetic switch in a sealed glass tube, enclosed together with its operating coil in a steel-vacuum-tube-type housing with an octal base.

At the top of the switch element, there are two leads of 52 (52 per cent nickel and 48 per cent iron) alloy which are sealed into the glass, one connecting with the front contact, which closes when the relay is operated; the other connecting with the back contact, which closes when the relay is released. The alloy used matches the thermal expansion characteristics of the glass and has good ferromagnetic characteristics—similar to those of 45 Permalloy (45 per cent nickel and 55 per cent iron).

The upper pole-piece is a plate of Permalloy welded to the front contact lead. The front contact proper is a rectangular bar of platinum welded across this pole-piece. The back contact is a similar platinum bar on a nonmagnetic supporting plate.

The armature contact element consists of two vertical wires tangent to each other, the groove between them forming a capillary path for the mercury. A rectangular Permalloy plate with two Permalloy wires welded on it forms the armature and extends the capillary downward.

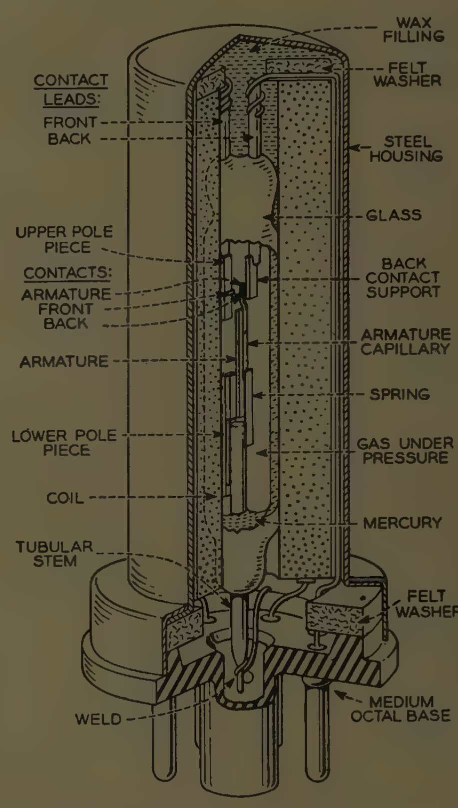


Figure 2. Mercury contact relay

The main operating gap is between the top of the armature and the bottom of the upper pole-piece, the travel of the armature at this gap being limited by both electric contacts.

The armature is connected to a tubular stem at the bottom through a flat steel spring. A lower pole-piece on the side of the armature opposite the spring provides a relatively large area hinge gap as a magnetic connection to this stem. The spaces between the armature, spring, and lower pole-piece are filled with mercury, extending the capillary connection and providing some fluid damping of the armature motion.

The tubular stem, also of 52 alloy, is sealed through the glass at the bottom. Mercury and hydrogen under

Essential substance of a conference paper presented at a joint session of the AIEE Midwest general meeting and the National Electronics Conference, Chicago, Ill., November 4, 1947.

J. T. L. Brown and C. E. Pollard are members of the technical staff of Bell Telephone Laboratories, New York, N. Y.

pressure are introduced through this stem. It is sealed off at the bottom of the switch by welding.

The complete switch and coil are wired to the octal base and held in position by a filling of high melting point wax. The steel housing serves as a magnetic shield and as a loosely connected return path for the switch.

MODIFICATIONS

The present model switch, which is functionally similar to the original design, has four fixed contacts, two front and two back, all of which engage a common armature. The supports for the contacts are extensions of four 52 alloy lead wires which are sealed in at the top of the switch. The extensions of the back contact leads are nonmagnetic. Formed platinum contacts are welded to these supports. Their contacting surfaces are cylindrical, with vertical axes. The armature contact is of double platinum wire, formed into a T, with two horizontal arms to engage the fixed contacts on either side.

All of the rest of the switch is identical with the previous model. Except for the wiring of the base the coil and housing also are unchanged essentially.

An available modification of the relay structure includes a permanent magnet which provides a bias that can be adjusted, after the relay is completed, to obtain desired sensitivity characteristics within narrow limits.

MERCURY CONTACT BEHAVIOR

The physical behavior of the mercury contacts in these relays is particularly interesting. When operating current is applied to the coil of the relay, the armature is drawn from the back to the front contacts. As the contact elements separate, a filament of mercury is formed between each pair of contacts which becomes narrower in cross section and finally breaks at two points, allowing a small drop of mercury to fall out. A similar filament is formed from each front contact when the relay is released. This process is illustrated in Figure 3. The photographs were obtained with the earlier model but the behavior shown is essentially indentical with that of the new type. It will be noted that the actual rupture of the filament takes place very rapidly. It is estimated that the acceleration of contact separation on each side of the mercury drop is of the order of 1,500 times that of gravity at the instant rupture occurs.

On contact closure, the connection is established between liquid surfaces. Once established, this connection bridges any mechanical chatter, and no chatter appears in the electric circuit.

CHARACTERISTICS

Typically, the unbiased relay just operates to close the front contacts when 157 ampere turns are applied to the coil, and just releases to close the back contacts when the coil input is reduced to 115 ampere turns. The armature normally will not assume a stable position in which it does not touch either the front or back contacts.

Figure 4 shows typical characteristics of operating and release time as a function of ampere turns applied, for a relay of average sensitivity. The values *OB* minus *OF*, and *RF* minus *RB* correspond to the "continuity" time. Normally this time is positive, the transfer being of the make-before-break type. It increases with increase in speed of operation and is typically about 0.5 millisecond in circuits where the relay operation is controlled by a contact and the voltage supply to the coil is well in excess of the just-operate value.

If, instead of being applied suddenly, the voltage is changed gradually through the just-operate and just-release values, the continuity time usually will be negative—the transfer becomes open instead of bridging.

All of the afore-mentioned applies to single operations, separated by enough time for the mercury to come to equilibrium. This is in the order of 100 milliseconds or more. If sufficient time has not elapsed since the previous operation for equilibrium of the mercury to be restored, values may be changed considerably. For periodic operation at 60 cycles per second, for instance, the average continuity time is negative, being about -0.3 millisecond.

STABILITY

A striking illustration of the stability of the relay is given in the two parts of Figure 2. The switch shown was operated at 60 cycles per second in an open center coil to permit viewing. A still camera and a stroboscopic light source were used, the phase setting between the relay drive and the light flash being adjustable in accordance with the time scale indicated. The exposure time was one minute, or 3,600 individual flashes. Instability would be indicated, therefore, by poor definition in the illustrations.

Although there has been some retouching for reproduction purposes, the outline of the mercury filament in the first six frames and the ball in the last frame are at least as clear in the original photographs as in these reproductions. The break which takes place in the 0.09-millisecond interval between the sixth and seventh frames also is well defined.

POSITION AND ACCELERATION

If the relay is tilted from the vertical position, the negative head between the mercury reservoir and the contacts is reduced. For angles up to about 30 degrees from the vertical, the only effect is an increase of the order of 50 per cent in the continuity time. For angles much greater than this or for external acceleration producing an equivalent effect, the mercury tends to short-circuit the switch by filling the space between the fixed contacts. When the relay is righted after this condition, it should be allowed to rest in both operated and released positions for a few seconds to drain off excess mercury from the fixed contacts.

It is of interest that, in spite of these limitations, a

large percentage of the relays manufactured went into air-borne equipment for communication and similar purposes.

CONTACTS

Study of the electrical behavior of the contacts on closure indicates that, if the rate of current rise does not exceed 25 amperes per microsecond, low resistance contact is established in 10^{-7} second or less. Above this rate of current rise, a discontinuity appears, the duration of which is about one to three microseconds. This indicates that a mercury bridge is formed which vaporizes if the energy dissipated in it exceeds a critical amount. Tests have shown that there is no damage to the platinum contact unless the amount of mercury vaporized is sufficient to remove the protecting layer of mercury.

The actual surge currents which the contacts are able to withstand without damage are quite high. A completely safe operating criterion in this connection is that the contact should not show a visible spark on closure. This condition appears to be satisfied if the circuit voltage does not exceed 50 volts, or, for higher voltages, if the discharge from a capacitor across the contacts does not exceed 40 microjoules. To avoid damage to the glass seals by heating-current through the switch should be limited to a total of about five amperes rms through the glass seal at either end.

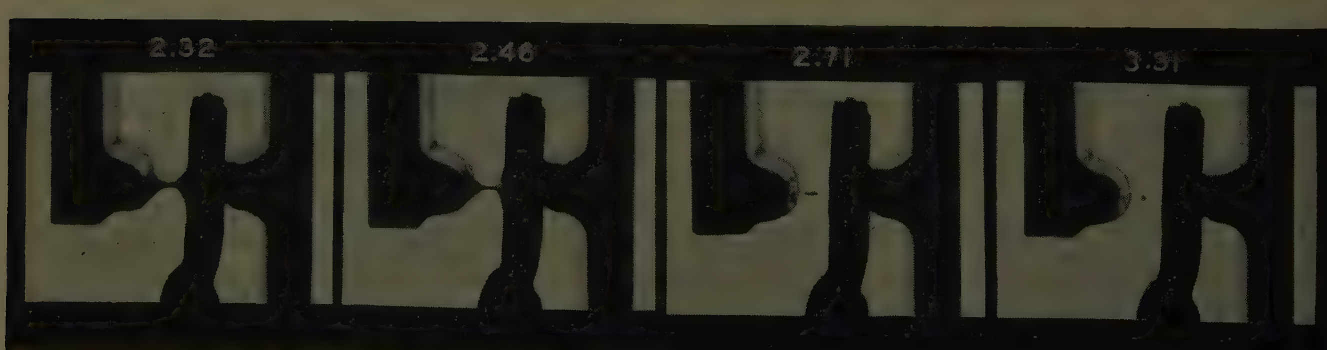
The high gas pressure makes the contact gap capable of withstanding a high voltage gradient without breakdown. Because of this, and the high speed at which the gap increases when the mercury filament breaks, a high rate of voltage rise and a high peak voltage can develop across a contact which is opening, without producing an arc. The maximum voltage rise without arcing decreases with increase of current in the circuit, presumably because of heating of the mercury filament just before it breaks. For currents up to one ampere this maximum safe rate of rise is about 5 volts per microsecond. The fully open contact gap inside the switch breaks down at about 8,500 volts.

Up to the point where vaporization appreciably reduces the supply of mercury, operation of the relay under conditions in which arcing is produced on opening the circuit has no adverse effect on the contacts themselves. However, severe arcing over a long period of use causes the glass walls adjacent to the contacts to become coated with particles of platinum and nickel amalgam. Mercury collecting on this coating gradually builds up into a drop sufficiently large to touch the fixed contacts and cause a short circuit of several seconds duration in draining off.

The high peak voltage that can develop across the opening contact makes it necessary in most applications to insure against insulation breakdown in the external circuit. This ordinarily requires a capacitor to be bridged across the contacts. In many cases the capability of the contacts for withstanding high current on closure makes it unnecessary to insert resistance or inductance in series with the bridged capacitor. This provision for peak voltage limitation usually limits the

Figure 3. Stroboscopic photographs showing formation and rupture of mercury filament between back contact and armature

Figures indicate time scale in milliseconds



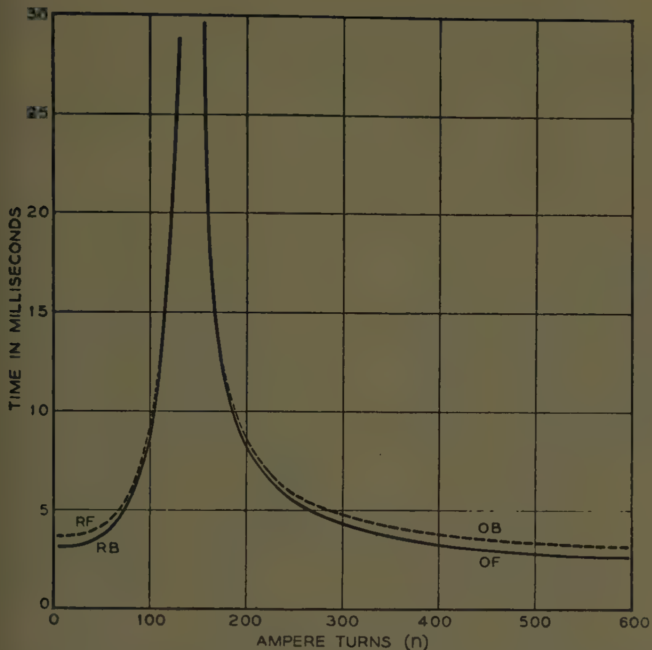


Figure 4. Operating and releasing times of unbiased relay

OF—Operating time to make front contacts
OB—Operating time to break back contacts
RB—Releasing time to make back contacts
RF—Releasing time to break front contacts

rate of voltage rise on opening so that no appreciable arcing takes place.

LIFE TESTS

The principal effects which have been noted in life tests on recent models of these relays with protected contact leads have been small and gradual changes in sensitivity, of the order of 2 to 5 ampere turns over-all in a billion operations. The changes are roughly proportional to the logarithm of the number of operations and are generally in the direction of increased sensitivity with time.

In some early models life of over three billion operations was obtained without failure in tests at 20–30 volts, 0–1 ampere.

APPLICATIONS

The emergence of these relays from the laboratory to manufacture was stimluated by their adaptability for motor drive in servomechanisms. Here the relays, in a balanced pair, are driven by an a-c input, usually 60 cycles per second, superposed on a variable d-c signal bias. The contacts are connected so as to give a motor input in the form of power pulses of variable duration and polarity under control of the signal bias.

A few applications have used the relays as converters and synchronous rectifiers. Here they have some advantage in power capacity and life over ordinary mechanical devices and higher efficiency than tubes in low-voltage circuits. One complication in many of these

Table II. Typical Mercury Contact Relay Characteristics

Characteristic	Value: Unbiased	Value: Biased
Designation	275C	276D
Over-all length, inches	3.20	3.67
Outside diameter, inches	1.31	1.31
Base	Medium octal	Medium octal
Primary winding:		
Terminals	7–8	7–8
Resistance, ohms	700	4,000
Turns	5,925	23,400
Just operate, milliamperes	26.5	+1.0
Just release, milliamperes	19.6	−1.0*
Secondary winding:		
Terminals	5–6	
Resistance, ohms	3,300	
Turns	16,950	
Just operate, milliamperes	9.3	
Just release, milliamperes	6.8	

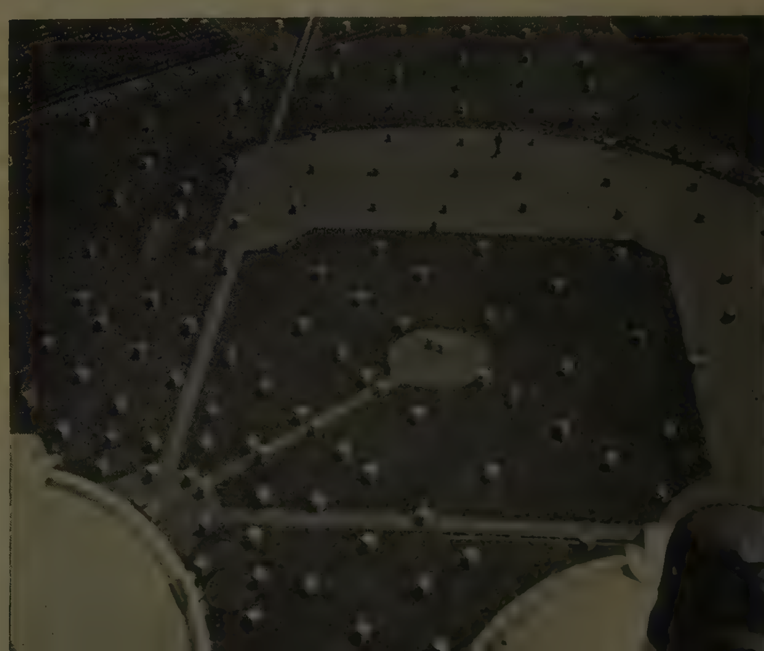
*Opposing magnet.

power applications is the need for a series impedance to prevent the power supply from being short-circuited during the continuity interval.

The most important characteristics of these relays from the standpoint of telephone plant switching are their relatively high speed and capability of uniform performance over a long period of unattended life. They now are being used in a number of important switching applications, for some of which no satisfactory substitute would be available. The results of these tests thus far are encouraging.

Targets for Floodlights

Precise aiming of floodlights is one of the secrets of successful sports field floodlighting. Each of the hundreds of lights must be directed at a slightly different spot to illuminate the play properly and at the same time to keep glare from the spectators' and players' eyes. Here the packing boxes in which the lights originally were shipped from the Westinghouse Electric Corporation are arranged on the Polo Grounds of the New York Giants according to a predetermined plan to act as targets. A rifle sight built into each light makes it possible to aim the lights in daylight.



PCM Distortion Analysis

A. G. CLAVIER P. F. PANTER D. D. GRIEG
ASSOCIATE AIEE

PCM, pulse count modulation, is a recent development in the field of pulse time multiplexing. Computations and experimental work indicate that accepted standards of telephone transmission over wire and radio commercial systems can be obtained with a relatively small number of quantization levels.

BECAUSE pulses are characterized by the several parameters of amplitude, timing, duration, frequency, build-up time, decay time, and pulse shape, a large number of modulation methods involving these characteristics singly or in combination may be envisaged. In addition to pulse amplitude modulation, pulse width modulation, pulse time modulation, and others, a second class of modulating methods complementary to these previous methods can be derived in which only selected amplitude values are transmitted, that is, a double system of discreteness is utilized involving both amplitude sampling as well as time sampling. In this, the amplitude range is divided into a number of discrete levels. If the instantaneous amplitude of the signal to be transmitted falls between two levels, either the lower or upper level only is transmitted, depending upon the level which is closest.

Since only a finite number of levels is involved it is possible to transmit the information by a coded pulse system similar to the standard printing telegraph system. A transmission system of this type has been termed PCM. Thus, for example, if a modulating signal is divided into a total of 31 levels a five unit binary numbering system may be used for identifying each of the discrete amplitudes. In this example all numbers from 0 to 31 would be transmitted in terms of zero and unity, or absence and presence of pulse respectively. Zero is transmitted as 00000, one is transmitted as 00001, two is transmitted as 00010, three is transmitted as 00011, four is transmitted as 00100, and so forth.

It is apparent that with this transmission system the many advantages that are obtained with teletype likewise could be extended to voice transmission. For example, cross talk introduced through carry-over from one pulse to the adjacent pulse is minimized since only the presence or absence of a pulse characterizes the intelligence. A similar situation is true with reference to noise introduced into the system. In order to deteriorate transmission, noise pulses must occur with the proper amplitude and at the proper time and phase in order to introduce a spurious pulse or suppress an existing one. Since the probability of noise occurring under these conditions is relatively small, the system permits a large signal-to-noise improvement factor to be obtained. A further advantage of pulse count modulation is that the transmission band width may be made relatively small to the extent of producing considerable carry-over from one pulse to the next without affecting the transmitting capabilities.

With a pulse system involving the single discreteness of time sampling only, a minimum of modulation distortion occurs provided sufficient samples in time are taken to delineate properly the modulating signal. For pulse amplitude modulation the minimum ratio of pulse sampling frequency to the modulating frequency band width is two to one. With PCM a similar relation holds insofar as spurious frequency distortion is concerned, however, since only an approximation in amplitude of the modulating signal is produced, it is obvious that a price must be paid in terms of nonlinear distortion for the teletype advantages gained. An increase in the number of levels utilized decreases this distortion, but the number of pulses required is increased and hence the band width necessary to accommodate the system is increased accordingly. The degree of distortion with a system of this type thus determines to a large extent the transmission characteristics.

A study has been made of the relationship between the number of levels and the resulting distortion as well as the relation between the cross talk and this distortion in a PCM system. The purpose of the present article is to indicate the several aspects of these characteristics resulting from the study, as well as the special methods of analysis which were found necessary to solve the problem, and which are applicable to similar problems of this type.

PCM APPLIED TO A SIGNAL CONSISTING OF ONE SINE WAVE

General. It is well known that when an infinite train of square topped pulses is used in pulse amplitude modulation to scan a sine wave, the output spectrum does not contain any harmonics of the modulating frequency. However, in a PCM system, due to the discrete nature

Essential substance of paper 47-152, "Distortion in a Pulse Count Modulation System," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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of the sampling process, it is to be expected that harmonic distortion would be produced dependent on the number of amplitude levels used in the transmission of the intelligence. In the limit, when the number of amplitude levels is increased greatly, a PCM system will convert to the equivalent of a pulse amplitude modulation system with no harmonic distortion in the output.

In order to calculate the distortion introduced in the system when PCM is applied to a sine wave, one can replace the signal with a step function consisting of $2N$ levels of equal height. In this representation, the system will recognize amplitudes to the nearest half level. Obviously applying pulse amplitude modulation to such a step function is equivalent to applying PCM to a sine wave, for the modulated pulses carring the intelligence will be identical for two cases and thus the harmonic distortion of such a step function must equal the distortion introduced in the process of PCM.

Calculation of Harmonic Distortion of the Step Function. Consider a sine wave $f(t)=A \sin \omega t$ to be replaced by a step function $f_s(t)$. This step function may be considered as a superposition of N pairs of rectangular steps per cycle of the same period T equal to that of the fundamental sine wave, of the same height A/N and of different width t_k such that

$$t_k=\frac{T}{2}-\frac{2}{\omega}\sin^{-1}\frac{2k-1}{2N} \tag{1}$$

It can be shown that the kth rectangular step pair may be represented by the Fourier series

$$\sigma_k(t)=\sum_{\nu=0}^{\infty}\frac{4A}{\pi N(2\nu+1)}\cos\left[(2\nu+1)\sin^{-1}\frac{2k-1}{2N}\right]\times \sin(2\nu+1)\omega t \tag{2}$$

only odd harmonics being present and

$$f_s(t)=\sum_{k=1}^{N}\sum_{\nu=0}^{\infty}\frac{4A}{\pi N(2\nu+1)}\cos\left[(2\nu+1)\sin^{-1}\frac{2k-1}{2N}\right]\times \sin(2\nu+1)\omega t \tag{3}$$

The harmonic distortion of $f_s(t)$ is defined by

$$D=\frac{\sqrt{\sum_{\nu=1}^{\infty}(A_{2\nu+1})^2}}{A_1} \tag{4}$$

where $A_{2\nu+1}$ equals the amplitude of the $(2\nu+1)$th harmonic of the step function $f_s(t)$, namely,

$$A_{2\nu+1}=\frac{4A}{\pi N(2\nu+1)}\sum_{k=1}^{N}\cos\left[(2\nu+1)\sin^{-1}\frac{2k-1}{2N}\right] \tag{5}$$

It also can be shown that equation 4 reduces to

$$D=\frac{\sqrt{\bar{A}^2-A_1^2}}{A_1} \tag{6}$$

where

$$\bar{A}^2=\frac{2A^2}{N^2}\left[N^2-\frac{2}{\pi}\sum_{k=}^{N}(2k-1)\sin^{-1}\frac{2k-1}{2N}\right] \tag{7}$$

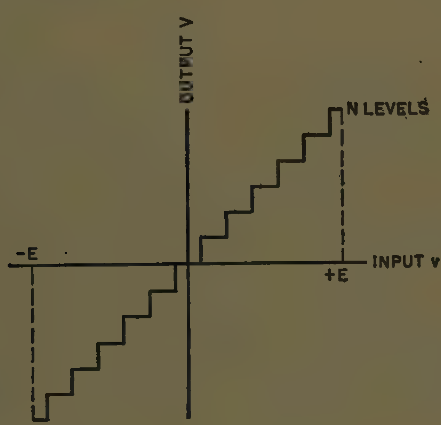

Figure 1. Transfer function characteristic in PCM

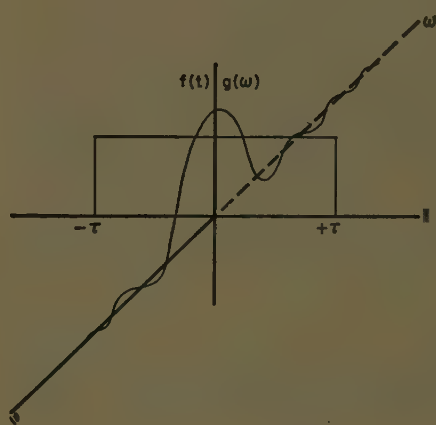

Figure 2. Fourier transform pair

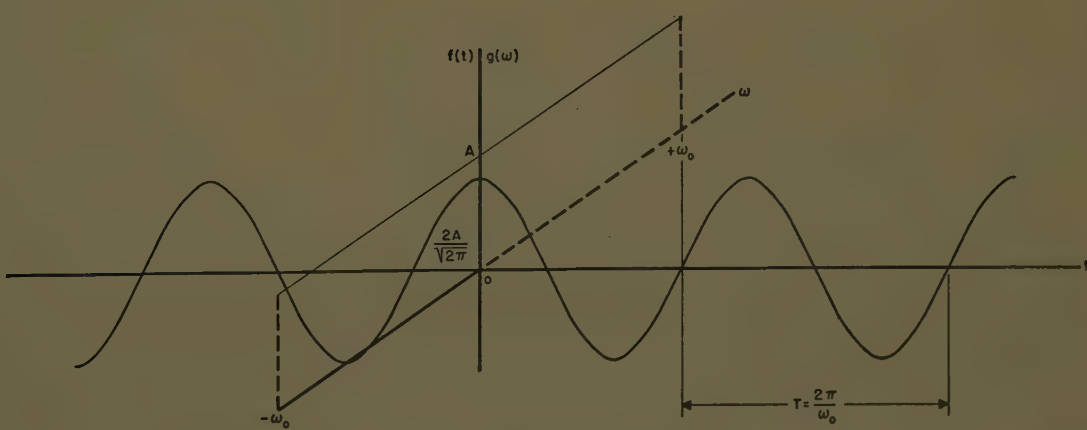

Figure 3. Fourier transform of a cosine function

and A_1 equals the amplitude of the first harmonic of $f_s(t)$ given by

$$A_1=\frac{4A}{\pi N}\sum_{k=1}^{N}\cos\left(\sin^{-1}\frac{2k-1}{2N}\right) \tag{8}$$

Numerical Results. No closed form was found for the distortion formula given by equation 6. However, this formula is useful for numerical calculations and the results are tabulated in Table I.

It is seen that the distortion components are always odd harmonics of the fundamental. Also from Table I for N large the distortion D approaches $1/\sqrt{6}N$ which is a very interesting limit of equation 6 and which remains to be proved mathematically.

PCM APPLIED TO A SIGNAL OF TWO SINE WAVES

General. The method outlined in the previous paragraph is applicable to the simple case of one modulating frequency. However, for composite modulating signals other methods must be devised, one of which is outlined in the following paragraph and which is applicable to a small number of modulating signals. In this case one would expect to find in the output not only the original frequencies of the modulating signal, but also intermodulation products, that is, all possible additive and subtractive combinations of the input frequencies and their harmonics.

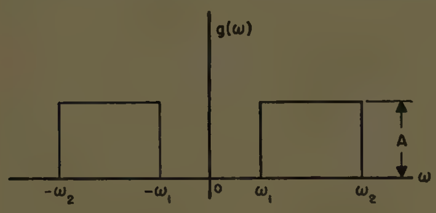

Figure 4. Frequency spectrum of modulating signal

For an ordinary nonlinear system where the output voltage V can be expressed as a power series of the input v, namely,

$$V=av+bv^2+\ldots$$

attempts have been made to calculate the cross talk introduced. However, in a PCM system the output–input characteristic is a step function having a finite number of discontinuities and thus cannot be expressed in a power series.

To calculate the harmonic distortion and cross talk components introduced, the output V is expressed as a Fourier series of the input v within the operating range of the modulating signal. Expressing v as a function of time, namely,

$$v=\sum_{k=1}^{n}E_k\sin\omega_k t$$

the output signal V thus is given as a function of time which then is analyzed into its frequency components. This method was applied to a signal consisting of one or two sine waves. The formulas developed in the preceding section were derived in a different form and their usefulness was extended. New relations were developed for the case of two frequencies which are very interesting from the mathetical point of view, but too complex from the engineering point of view. In the following paragraphs a short résumé of this method is given.

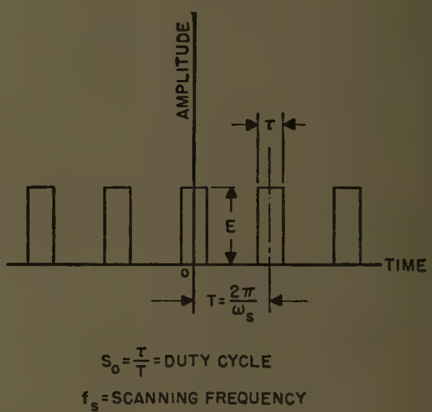

Figure 5. Series of scanning pulses

Fourier Analysis of a Step Function Characteristic of Output Versus Input in a PCM System. Because of the discrete nature of the transmission of intelligence in a PCM system the output–input curve is in the form of a function as shown in Figure 1. In this representation the system is

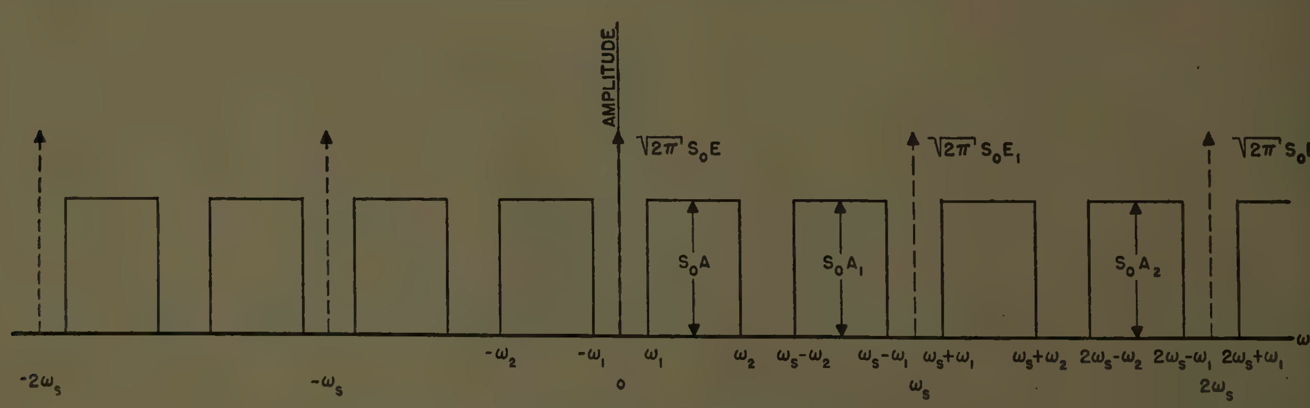

Figure 6. Frequency spectrum of "exact scanning" process

assumed to recognize amplitude levels to the nearest half level.

The output V may be expressed as a Fourier series of the input v in the range

$$-E \leq V \leq E$$

$$V=\sum_{n=1}^{\infty} B_n \sin \frac{n\pi v}{E} \tag{9}$$

where

$$B_n=\frac{2E}{\pi n N}\left[\frac{\sin \pi n}{2 \sin \frac{\pi n}{2N}}+N(-1)^{n-1}\right] \tag{10}$$

therefore

$$V=\frac{2E}{\pi N}\sum_{n=1}^{\infty}\left\{\frac{1}{n}\left[\frac{\sin \pi n}{2 \sin \frac{\pi n}{2N}}+N(-1)^{n-1}\right]\right\} \sin \frac{n\pi v}{E} \tag{11}$$

In equation 11, v must be expressed as a function of time making sure that v is always within the range considered, and by analyzing the output V, the different components of the output may be determined. Two cases will be analyzed here:

$$v=E \sin \omega t$$

$$v=\frac{E}{2}(\sin \omega_1 t+\sin \omega_2 t)$$

Input Signal Consisting of a Sine Wave $v=E \sin \omega t$. Equation 11 becomes

$$V=\frac{2E}{\pi N}\sum_{n=1}^{\infty}\left\{\frac{1}{n}\left[\frac{\sin \pi n}{2 \sin \frac{\pi n}{2N}}+N(-1)^{n-1}\right]\sin (\pi n \sin \omega t)\right\}$$

$$=\frac{4E}{\pi N}\left[N\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{n}+\sum_{n=1}^{\infty}\frac{\sin \pi n}{2n \sin \frac{\pi n}{2N}}\right]\times \sum_{\nu=0}^{\infty} J_{2\nu+1}(\pi n) \sin (2\nu+1)\omega t \tag{12}$$

where $J_{2\nu+1}$ represent the Bessel function of the order $(2\nu+1)$.

From equation 12 it is seen that the output V consists of the fundamental frequency plus odd harmonics only, a result which has been outlined in "Calculation of Harmonic Distortion of the Step Function." The amplitude of the fundamental frequency in the output A_1 reduces to

$$A_1=E\left[1-\frac{2}{\pi N}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l} J_1(2\pi l N)\right]$$

$$=\frac{4E}{\pi N}\sum_{k=1}^{N} \cos \left(\sin^{-1}\frac{2k-1}{2N}\right) \tag{13}$$

and the amplitude of the $(2\nu+1)$th harmonic becomes

$$A_{2\nu+1}=-\frac{2E}{\pi N}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l} J_{2\nu+1}(2\pi l N)$$

$$=\frac{4E}{\pi N(2\nu+1)}\sum_{k=1}^{N} \cos \left[(2\nu+1) \sin^{-1}\frac{2k-1}{2N}\right] \tag{14}$$

The last two equations are identical with equations 5 and 8.

By using the asymptotic expansion for $J_1(2\pi l N)$ equation 13 may be expressed in a closed form, namely,

$$A_1 \approx E\left[1+\frac{\sqrt{2}}{\pi^2 N^{3/2}}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l^{3/2}}\right]=E\left[1+\frac{0.1096}{N^{3/2}}\right] \tag{15}$$

The values computed for A_1 for different levels N are compared with those of Table I and are shown in Table II.

An approximate expression for $A_{2\nu+1}$ also was found.

$$A_{2\nu+1} \approx \frac{(-1)^{\nu}\sqrt{2}E}{\pi^2 N^{3/2}}\left[0.7650-\frac{0.8670[4(2\nu+1)^2-1^2]}{16\pi N}-\frac{0.9278[4(2\nu+1)^2-1^2][4(2\nu+1)^2-3^2]}{512\pi^2 N^2}\right] \tag{16}$$

One must realize that the labor involved in the calculation of $A_{2\nu+1}$ is very great when using the exact formula of equation 5, especially when N is large. It should be observed, however, that for large N only two terms of equation 16 will suffice.

Input Signal Consisting of Two Sine Waves $V=\frac{E}{2}\times(\sin \omega_1 t+\sin \omega_2 t)$. The method used in the preceding section may be extended to two frequencies. Equation 11 reduces to

$$V=\frac{E}{2}(\sin \omega_1 t+\sin \omega_2 t)-\frac{2E}{\pi N}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l}\times$$

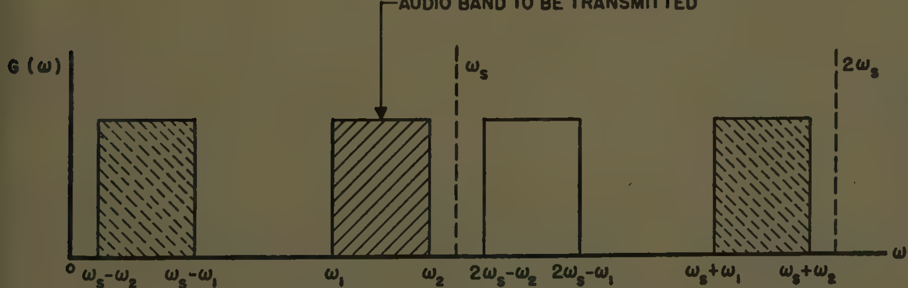

Figure 7. Side-band distribution ($\omega_2 < \omega_S < 2\omega_1$)

Figure 8. Frequency spectrum of modulating signal, one channel unoccupied

Table I. Per Cent Distortion in a PCM System for Different Levels

N, Number of Levels Per Half Cycle	A_1, Amplitude of First Harmonic, Per Cent of A	D, Per Cent of Distortion	$\frac{1}{\sqrt{6}N}\times 100$
5	100.97	7.55	8.16
10	100.34	3.80	4.09
20	100.12	2.00	2.04
50	100.03	.81	.816

$$\Big\{J_0(\pi lN)\Big[\sum_{\nu=0}^{\infty}J_{2\nu+1}(\pi lN)\sin(2\nu+1)\omega_1t+\sum_{\rho=0}^{\infty}J_{2\rho+1}(\pi lN)\sin(2\rho+1)\omega_2t\Big]+2\sum_{\nu=0}^{\infty}\sum_{\lambda=1}^{\infty}J_{2\nu+1}(\pi lN)\sin(2\nu+1)\omega_1t\times\cos 2\lambda\omega_2t+2\sum_{\rho=0}^{\infty}\sum_{\eta=1}^{\infty}J_{2\rho+1}(\pi lN)\times J_{2\eta}(\pi lN)\sin(2\rho+1)\omega_2t\times\cos 2\eta\omega_1t\Big\}\tag{17}$$

The amplitudes of the odd harmonics of the two input frequencies ω_1 and ω_2 are given by

$$A'_{2\nu+1}=-\frac{2E}{\pi N}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l}J_0(\pi lN)J_{2\nu+1}(\pi lN)\ (\text{where } \nu\geq 1)\tag{18}$$

The similarity between this result and equation 14 in the case of one frequency is interesting.

The amplitudes of the cross products are given by

$$A_{(2\nu+1)\omega_1\pm 2\lambda\omega_2}=-\frac{2E}{\pi N}\sum_{l=1}^{\infty}\frac{(-1)^{l-1}}{l}J_{2\nu+1}(\pi lN)J_{2\lambda}(\pi lN)\tag{19}$$

APPLICATION OF THE FOURIER TRANSFORMATION TO PAM MODULATING SIGNAL CONSISTING OF A CONTINUOUS FREQUENCY BAND

General. When the modulating signal consists of a continuous frequency band, the method outlined previously fails due to the complexity of the mathematics encountered. However, such an analysis can be made by the use of Fourier transforms at first applied to pulse amplitude modulation and then extended to PCM.

The results obtained in pulse amplitude modulation when the modulating signal consists of a sine wave are generalized for a complex modulating signal in the following analysis. The components of the output spectrum and the frequency response thus are extended to a case which clearly corresponds to a practical communication problem, where the modulating signal is, or can be, constituted by all frequencies in the modulating band simultaneously.

The usefulness of Fourier transforms with their extensive and flexible properties will be shown still more clearly in the paragraph dealing with the computation of cross talk introduced in a PCM system, due to the process of quantization.

Introduction to the Theory of "Fourier Transforms." Consider first a signal given as a function of time $f(t)$, for instance the signal shown in Figure 2, to have a constant amplitude from $t=-\tau$ to $t=+\tau$. To this signal a Fourier transform can be associated which is obtained by means of the following mathematical operation:

$$T_t^{\omega}f(t)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty}f(t)\epsilon^{-i\omega t}dt\tag{20}$$

This is a function of ω, namely, $g(\omega)$, which for the particular signal considered readily is found to be

$$g(\omega)=\frac{2A\tau}{\sqrt{2\pi}}\cdot\frac{\sin\omega\tau}{\omega\tau}\tag{21}$$

The function also shown in Figure 2, but in a plane perpendicular to the t plane, usually is denominated the frequency spectrum of $f(t)$, for reasons which will appear more clearly later on.

It can be shown that all functions $f(t)$ such that the integral $\int_{-\infty}^{+\infty}|f(t)|dt$ exists are transformable by the previous mechanism into spectra $g(\omega)$ without ambiguity.

When $g(\omega)$ has been found it can be transformed conversely into the original signal $f(t)$ by the following operation:

$$T_\omega^{t}g(\omega)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty}g(\omega)\epsilon^{+i\omega t}d\omega\tag{22}$$

and all functions $g(\omega)$ for which $\int_{-\infty}^{+\infty}|g(\omega)|d\omega$ exists do not give rise to any theoretical difficulty.

The associated signal $f(t)$ and spectrum $g(\omega)$ constitute a regular pair of Fourier transforms, which property may be symbolized as follows:

$$\left.\begin{aligned}T_\omega^tT_t^\omega f(t)&=f(t)\\T_t^\omega T_\omega^t g(\omega)&=g(\omega)\end{aligned}\right\}\tag{23}$$

The value of the Fourier transformation comes from the fact that many problems can be solved by one of the following methods:

1. Starting from the signal, the spectrum is found. This spectrum is submitted to a modification resulting from the operation of a piece of apparatus, a filter for instance. The modified spectrum then is reconverted to the signal-time plane of co-ordinates.

2. Inversely, starting from the spectrum, the signal is found. This signal is modified by the operation which is considered. The modified signal then is reconverted to the spectrum-frequency plane of co-ordinates.

In the first instance the shape of the modified signal is compared with the original signal to see how far it is distorted; in the second instance the modified spectrum is compared with the original one, to investigate how much frequency distortion, or nonlinear distortion or cross talk, has been introduced by the process under examination. This second method rarely has been used so far, though

it easily is seen that, when the mathematical difficulties are not insuperable, it should prove to be a powerful instrument for the analysis of a number of problems with which the communication engineer is confronted.

General Properties of the Fourier Transforms. In order to facilitate the understanding of the following paragraphs, and to give an idea of the remarkable flexibility of the Fourier transformation, the following tabulation has been prepared, in which the essential properties of the Fourier transformation are listed.

1. Definitions and notations.

$$\left.\begin{aligned} T_t^\omega f(t) &= g(\omega) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} f(t)\epsilon^{-i\omega t}dt \\ T_\omega^t g(\omega) &= f(t) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} g(\omega)\epsilon^{+i\omega t}d\omega \end{aligned}\right\} \quad (24)$$

2. Change of sign of the variable.

$$\left.\begin{aligned} T_t^\omega f(-t) &= g(-\omega) \\ T_\omega^t g(-\omega) &= f(-t) \end{aligned}\right\} \quad (25)$$

3. Translation of the variable.

$$\left.\begin{aligned} T_t^\omega f(t-t_0) &= \epsilon^{-j\omega t_0} g(\omega) \\ T_\omega^t g(\omega-\omega_0) &= \epsilon^{j\omega_0 t} f(t) \end{aligned}\right\} \quad (26)$$

4. Interchange of function.

$$\left.\begin{aligned} T_t^\omega g(t) &= f(-\omega) \\ T_\omega^t f(\omega) &= g(-t) \end{aligned}\right\} \quad (27)$$

5. Multiplication of functions.

$$\left.\begin{aligned} T_t^\omega f_1 f_2 &= \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} g_1(-x)g_2(\omega+x)dx \\ T_\omega^t g_1 g_2 &= \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} f_1(x) f_2(t-x)dx \end{aligned}\right\} \quad (28)$$

6. Differentiation and integration with respect to the variable.

$$\left.\begin{aligned} T_t^\omega \frac{df}{dt} &= j\omega_1 g(\omega) \\ T_\omega^t \frac{dg}{j\,d\omega} &= -t\times f(t) \end{aligned}\right\} \quad (29)$$

$$\left.\begin{aligned} T_t^\omega \int_{-\infty}^{t} f(t)\,dt &= \frac{1}{j\omega} g(\omega) \\ T_\omega^t j\int_{-\infty}^{\omega} g(\omega)d\omega &= -\frac{1}{t}\times f(t) \end{aligned}\right\} \quad (30)$$

From these fundamental properties, a number of others can be derived, such as:

7. Computation of the sine and cosine Fourier integrals.

$$\left.\begin{aligned} \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} f(t)\cos\omega t\,dt &= \frac{1}{2}\,[g(\omega)+g(-\omega)] \\ \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} f(t)\sin\omega t\,dt &= j\cdot\frac{1}{2}\,[g(\omega)-g(-\omega)] \end{aligned}\right\} \quad (31)$$

8. Energy integrals.

$$\int_{-\infty}^{+\infty} f(t)^2dt = \int_{-\infty}^{+\infty} g(\omega)^2d\omega \quad (32)$$

The usefulness of Fourier transforms, however, can be increased still further when they are extended to include some important, though essentially singular, functions. This will be explained in the following fundamental case.

Consider the signal $f(t)$ shown in Figure 2. Let the domain of time during which $f(t)$ exists decrease and at the same time the amplitude increase so that $\int_{-\infty}^{+\infty} f(t)dt$ remains constant. For the particular signal of Figure 2, this means that $2A\tau$ will remain constant. However small τ may be, the signal has a well defined transform. When τ approaches zero, the limit constitutes an essentially singular function of time, which is zero for all values of time, except for $t=0$ for which, though the amplitude becomes infinite, the limit of the area covered remains finite. This is the "impulse function." It can be written conventionally $2A\tau\delta_0(t)$. The symbol $\delta_0(t)$ is equal to zero for all values of t except $t=0$, for which it is equal to $+1$.

Let it now be written tentatively that

$$T_t^\omega 2A\tau\delta_0(t) = \lim_{\tau\to 0} \frac{2A\tau}{\sqrt{2\pi}}\times\frac{\sin\omega\tau}{\omega\tau} = \frac{2A\tau}{\sqrt{2\pi}}$$

where $A\tau$ is a constant. That is to say,

$$T_t^\omega \delta_0(t) = \frac{1}{\sqrt{2\pi}} \quad (33)$$

It will be necessary to show that this is consistent with

$$T_\omega^t \frac{1}{\sqrt{2\pi}} = \delta_0(t)$$

To do this, it is only necessary to consider 1 as the limit of $\epsilon^{-\alpha|\omega|}$ for $\alpha + v\epsilon$ approaching zero. It is found that

$$T_\omega^t \frac{\epsilon^{-\alpha|\omega|}}{\sqrt{2\pi}} = \frac{1}{\pi}\times\frac{\alpha}{\alpha^2+t^2}$$

Now

$$\int_{-\infty}^{+\infty} \frac{1}{\pi}\times\frac{\alpha\,dt}{\alpha^2+t^2} = 1$$

Let α approach zero. This limit is obviously $\delta_0(t)$.

Table II. Amplitude of Fundamental Component of Output for Different Amplitude Level

N, Number of Levels Per Half Cycle	A_1/E (Equation 8)	A_1/E (Equation 15)
5	1.0097	1.0098
10	1.0034	1.0035
20	1.0012	1.0012
50	1.0003	1.0003

Thus, $\delta_0(t)$ and $\frac{1}{\sqrt{2\omega}}$ can be considered as a pair of Fourier transforms. Applying general property 4 gives, immediately,

$$T^t_\omega \delta_0(\omega) = \frac{1}{\sqrt{2\omega}} \qquad (34)$$

Property 3 gives

$$T^t_\omega \delta(\omega_0-\omega_0) = \frac{1}{\sqrt{2\omega}} e^{j\omega_0 t} \qquad (35)$$

and consequently,

$$T^t_\omega[\delta_0(\omega-\omega_0)+\delta_0(\omega+\omega_0)] = \frac{2}{\sqrt{2\pi}} \cos \omega_0 t \qquad (36)$$

This result is of fundamental importance because it gives a means to deal with discrete frequencies at the same time as continuous spectra. A cosine signal $\frac{2A}{\sqrt{2\pi}} \cos \omega_0 t$ will be represented in the spectrum-frequency plane by two impulse function $A\delta_0(\omega-\omega_0)$ and $A\delta_0(\omega+\omega_0)$ which is distinguished from the differential amplitudes of continuous spectra by means of the dotted lines (Figure 3).

The method previously used for analyzing pulse amplitude modulation and PCM has consisted in studying the modulation of a series of pulses by a cosine wave. The corresponding spectrum of the modulating wave was thus the one shown in Figure 3. If a certain band width has to be covered, say from ω_1 to ω_2, and in case the modulation process includes operations which lead to possible interaction of the different frequencies involved, it becomes necessary to consider a number of simultaneous pairs of impulse functions in the plane. This computation generally leads to a lengthy arithmetical combination of the discrete frequencies involved from which it is difficult to deduce a clear statement of the general case, where all frequencies in the band width considered are present simultaneously.

The Fourier transforms provide a powerful instrument in the treatment of such problems. For instance, the analysis of the operation of scanning and quantizing a number of cosine waves of equal amplitudes,

$$A \cos \omega_2 t + A \cos \omega_3 t + \ldots\ldots + A \cos \omega_n t$$

all situated within a band $\omega_1<\omega<\omega_2$ is replaced by the investigation of the signal corresponding to the spectrum given in Figure 4. Such a signal readily is found to be

$$f(t) = T^t_\omega g(\omega) = \frac{2A\omega_2}{\sqrt{2\pi}}\left[\frac{\sin \omega_2 t}{\omega_2 t} - \frac{\omega_1}{\omega_2}\frac{\sin \omega_1 t}{\omega_1 t}\right] \qquad (37)$$

Exact Scanning. By exact scanning a type of pulse modulation is meant in which the tops of the modulated pulses follow the modulating time function during the scanning interval.

Figure 4 gives the frequency spectrum of the composite modulating signal, the time function of which is given by equation 37.

The scanning pulses are represented in Figure 5. This is a periodic function which also can be represented by the Fourier series expansion:

$$F(t) = S_0 E\left[1+2\sum_{\nu=1}^{\infty}\frac{\sin \nu\pi S_0}{\nu\pi S_0}\cos \nu\omega s t\right] \qquad (38)$$

The corresponding frequency spectrum immediately is obtained (see equations 34 and 36):

$$G(\omega) T^\omega_t F(t) = \sqrt{2\pi} S_0 E\left[\delta_0(\omega)+\sum_{\nu=1}^{\infty}\frac{\sin \nu\pi S_0}{\nu\pi S_0}\{\delta_0(\omega-\nu\omega_S)+\delta_0(\omega+\nu\omega_S)\}\right] \qquad (39)$$

The exact scanning is equivalent to operating on $F(t)$ by $f(t)$ according to

$$F(t)\left\{1+\frac{1}{E}f(t)\right\} = \varphi(t) \qquad (40)$$

So that the resulting frequency spectrum is

$$T^\omega_t \varphi(t) = T^\omega_t F(t) + \frac{1}{E} T^\omega_t F(t)\times f(t) \qquad (41)$$

The first term represents the spectrum $G(\omega)$ of the unmodulated pulses. The second one is, according to equation 28,

$$\frac{1}{E} T^\omega_t F(t)\times f(t) = \frac{1}{E\sqrt{2\pi}} \times \int_{-\infty}^{+\infty} g(-x)\times G(\omega+x)dx \qquad (42)$$

that is to say,

$$\frac{1}{E} T^\omega_t F(t)\times f(t) = S_0 \int_{-\infty}^{+\infty} g(-x)\left\{\delta_0(\omega+\delta x) + \sum_{\nu=1}^{\infty}\frac{\sin \nu\pi S_0}{\nu\pi S_0}[\delta_0(\omega+x-\nu\omega_S)+\delta_0(\omega+x+\nu\omega_S)]\right\}dx \qquad (43)$$

The first term is equal to $g(-x)$ when $\omega+x=0$, that is, it reproduces $g(\omega)$. Any other term is equal to $g(-x)$ when $x=\nu\omega_S-\omega$ and $x=-\nu\omega_S-\omega$ and it is equal to $g(\omega-\nu\omega_S)+g(\omega+\nu\omega_S)$; or as $g(-x)=g(x)$ it is equal to $g(\nu\omega_S-\omega)+g(\nu\omega_S+\omega)$.

For any term ω varying within the limits assigned to it by Figure 4, $-\omega_2<\omega<-\omega_1$ and $\omega_1<\omega<\omega_2$. Thus the frequency spectrum of $\varphi(t)$ can be represented as shown in Figure 6. Where

$$A_\nu = A\frac{\sin \nu\pi S_0}{\nu\pi S_0}$$

$$E_\nu = E\frac{\sin \nu\pi S^0}{\nu\pi S_0} \qquad (44)$$

In order to be able to filter out the original audio band from the first sideband, a sufficient condition (for an ideal filter) is readily apparent in Figure 6. It is $\omega_S>2\omega_2$.

Actually this condition is sufficient, but not always necessary. Consider a continuous band of frequencies to be transmitted where $\omega_1\leqq\omega\leqq\omega_2$.

One easily can see from Figure 7 that provided $\omega_2<2\omega_1$ the side band can be filtered out with the aid of a band

pass filter when the scanning frequency is such that $\omega_2 < \omega_s < 2\omega_1$.

Square Topped Scanning. Let the modulated pulse train be square topped, and let the amplitude of the pulses be modulated by the time function $f(t)$ (equation 37) derived in the foregoing in such a manner that the value of $f(t)$ corresponding to the center of the pulse is effective in the modulation process.

The amplitude of the νth pulse can be written:

$$E_\nu = E + f(t)\delta_0(t - \nu T) \tag{45}$$

Let $P_T(t - \nu T)$ be a function which takes the value one

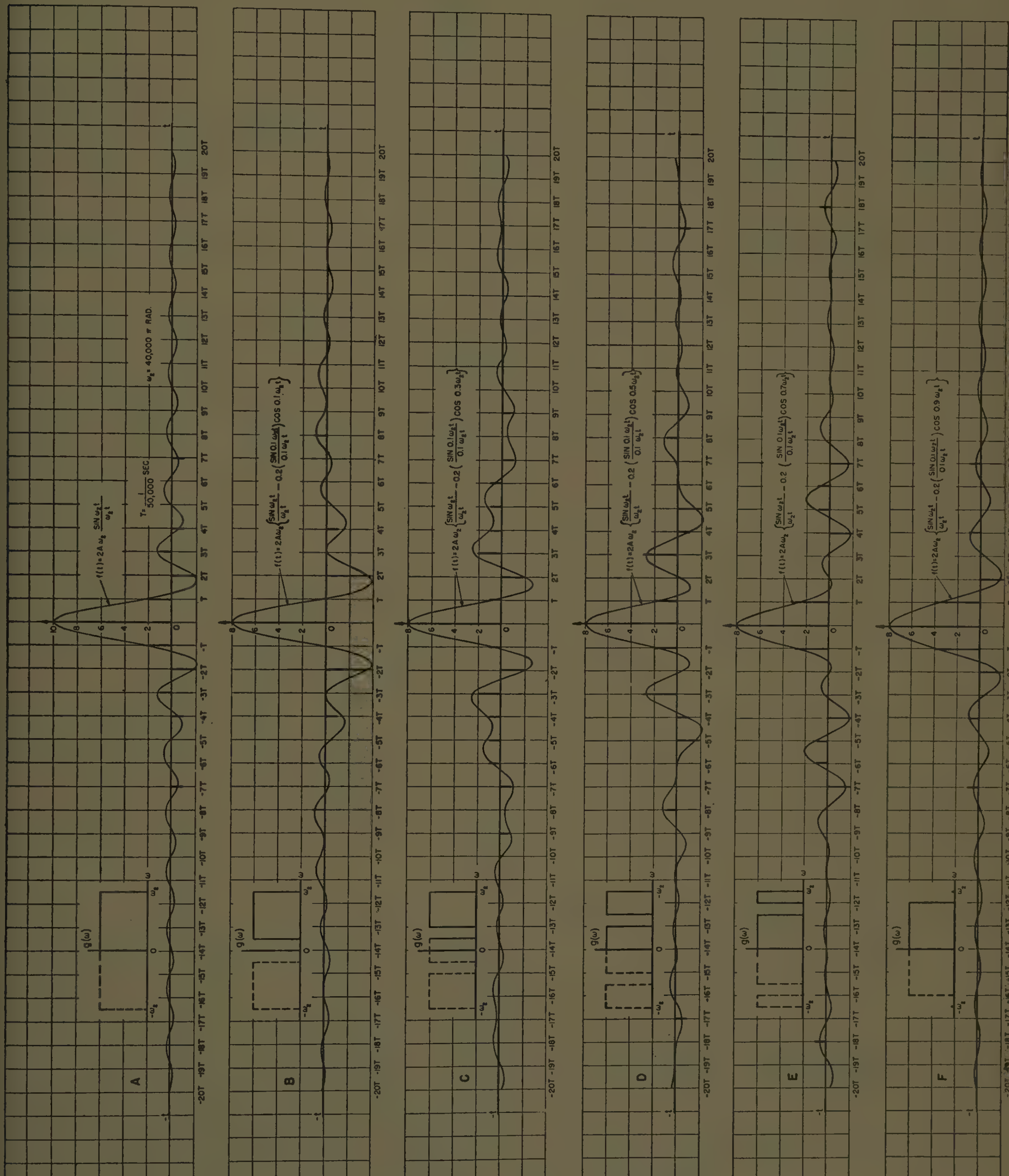

Figure 9. Time functions for various modulating signals

for all values of time such that $\nu T-\frac{\tau}{2}<t<\nu T+\frac{\tau}{2}$ and equals zero everywhere else. The function of time $\omega(t)$ corresponding to the modulated pulses can be written:

$$\varphi(t)=\sum_{\nu=-\infty}^{+\infty} E_\nu P_\tau(t-\nu T)$$

$$=\sum_{\nu=-\infty}^{+\infty} EP_\tau(t-\nu T)+\sum_{\nu=-\infty}^{+\infty}[f(t)\delta_0(t-\nu T)]P_\tau(t-\nu T) \qquad (46)$$

The problem consists in finding the spectrum of $\varphi(t)$

$$G(\omega)=T_t^\omega\varphi(t)=T_t^\omega\sum_{v=-\infty}^{+\infty} EP_\tau(t-\nu T)+$$

$$T_t^\omega\sum_{v=-\infty}^{+\infty}[f(t)\delta_0(t-\nu T)]P_\tau(t-\nu T)=G_1(\omega)+G_2(\omega) \qquad (47)$$

The first part clearly reproduces the spectrum of the original unmodulated pulse. The second part is due to the modulation.

Take any term of this second part:

$$T_t^\omega[f(t)\delta_0(t-\nu T)]P_\tau(t-\nu T)$$

$$=[f(t)\delta_0(t-\nu T)]T_t^\omega P_\tau(t-\nu T)$$

$$=[f(t)\delta_0(t-\nu T)]\epsilon^{-j\omega\nu t}T_t^\omega P_\tau(t) \qquad (48)$$

But

$$T_t^\omega P_\tau(t)=\frac{\tau}{\sqrt{2\pi}}\times\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}$$

Each term is thus equal to

$$\frac{\tau}{\sqrt{2\omega}}\times\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}[f(t)\epsilon^{-j\omega t}\delta_0(t-\nu T)] \qquad (49)$$

The second part is thus:

$$G_2(\omega)=\frac{\tau}{\sqrt{2\pi}}\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\times\sum_{\nu=-\infty}^{+\infty}[f(t)\epsilon^{-j\omega t}\delta_0(t-\nu T)] \qquad (50)$$

which immediately can be written:

$$G_2(\omega)=\frac{2A\tau\omega_2}{2\pi}\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\times\left[1-\frac{\omega_1}{\omega_2}+2\sum_{\nu=1}^{\infty}\left(\frac{\sin\omega_2\nu T}{\omega_2\nu T}-\frac{\omega_1}{\omega_2}\times\frac{\sin\omega_1\nu T}{\omega_1\nu T}\right)\cos\omega\nu T\right] \qquad (51)$$

Table III. Cross Talk in Unoccupied PCM Channels

Channel	Cross Talk, Per Cent
1	8.2
2	28.6
3	14.8
4	13.1
5	21.0

The expression $G_2(\omega)$ contains the spectrum of the modulation energy which will be analyzed subsequently. This can be accomplished either by an operational method applied to equation 50, an approach which is elegant and concise and which will be carried out here, or by standard algebraic methods using the form of equation 51.

Consider the operation

$$\sum_{\nu=-\infty}^{+\infty}\delta_0(t-\nu T)$$

of equation 50. This may be considered as a periodic process of interval T and thus can be represented by a Fourier series operator. Symbolically this may be written as

$$\sum_{\nu=-\infty}^{+\infty}\delta_0(t-\nu T)=\sum_{\nu=-\infty}^{+\infty}[B\nu]\times[\epsilon^{j\nu\omega_St}] \qquad (52)$$

where

$$[B\nu]=\left[\frac{1}{T}\int_{-\infty}^{+\infty}\delta_0(t)\epsilon^{-j\nu\omega_St}dt\right]=\left[\frac{1}{T}\int_{-\infty}^{+\infty}(1)\,dt\right]$$

Therefore

$$\sum_{\nu=-\infty}^{+\infty}\delta_0(t-\nu T)=\sum_{\nu=-\infty}^{+\infty}\times\left[\frac{1}{T}\int_{-\infty}^{+\infty}\epsilon^{j\nu\omega_St}\,dt\right] \qquad (53)$$

This means that for each term in equation 50 the operation

$$\frac{}{T}\int_{-\infty}^{+\infty}(f(t)\epsilon^{j\nu\omega_St})\times\epsilon^{-j\omega t}\,dt=\frac{\sqrt{2\pi}}{T}T_t^\omega[f(t)\epsilon^{j\nu\omega_St}] \qquad (54)$$

is performed so that $G_2(\omega)$ becomes

$$G_2(\omega)=\frac{\tau}{\sqrt{2\pi}}\times\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\times\frac{\sqrt{2\pi}}{T}\sum_{-\infty}^{+\infty}g(\omega-\nu\omega_S)$$

$$=S_0\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\sum_{-\infty}^{+\infty}g(\omega-\nu\omega_S) \qquad (55)$$

since

$$T_t^\omega f(t)=g(\omega)$$

Equation 55 contains, in a very compact form, all the information about the spectrum of the modulation energy.

Note that output components are identical with those obtained for the simple case where pulse amplitude modulation is applied to a single sine wave.

Conclusion. The preceding analysis shows that by the use of Fourier transforms it is possible to investigate the behavior of a band of modulating frequencies acting simultaneously in a given communication system. The generalization of the results obtained in the past for a small number of discrete modulating frequencies is ac-

complished with a surprising facility. This method of Fourier transforms however will reveal itself almost indispensable when the problem of PCM will be examined with a view to determine cross talk and distortion.

APPLICATION OF FOURIER TRANSFORMS TO THE CALCULATION OF CROSS TALK AND DISTORTION IN A PCM SYSTEM

It has been indicated previously that due to the discrete amplitude scanning, a PCM system will introduce cross talk. In practice, the total modulating frequency band $\omega_1 \leqq \omega \leqq \omega_2$ is divided into a number of channels, each channel carrying independent intelligence. Due to the cross talk introduced in any one of the channels, the problem reduces itself into calculating the energy appearing in a particular unoccupied channel in the band while the other channels are occupied. The concept of a time function, equation 56, being the Fourier transform of the modulating band of frequencies modulating an

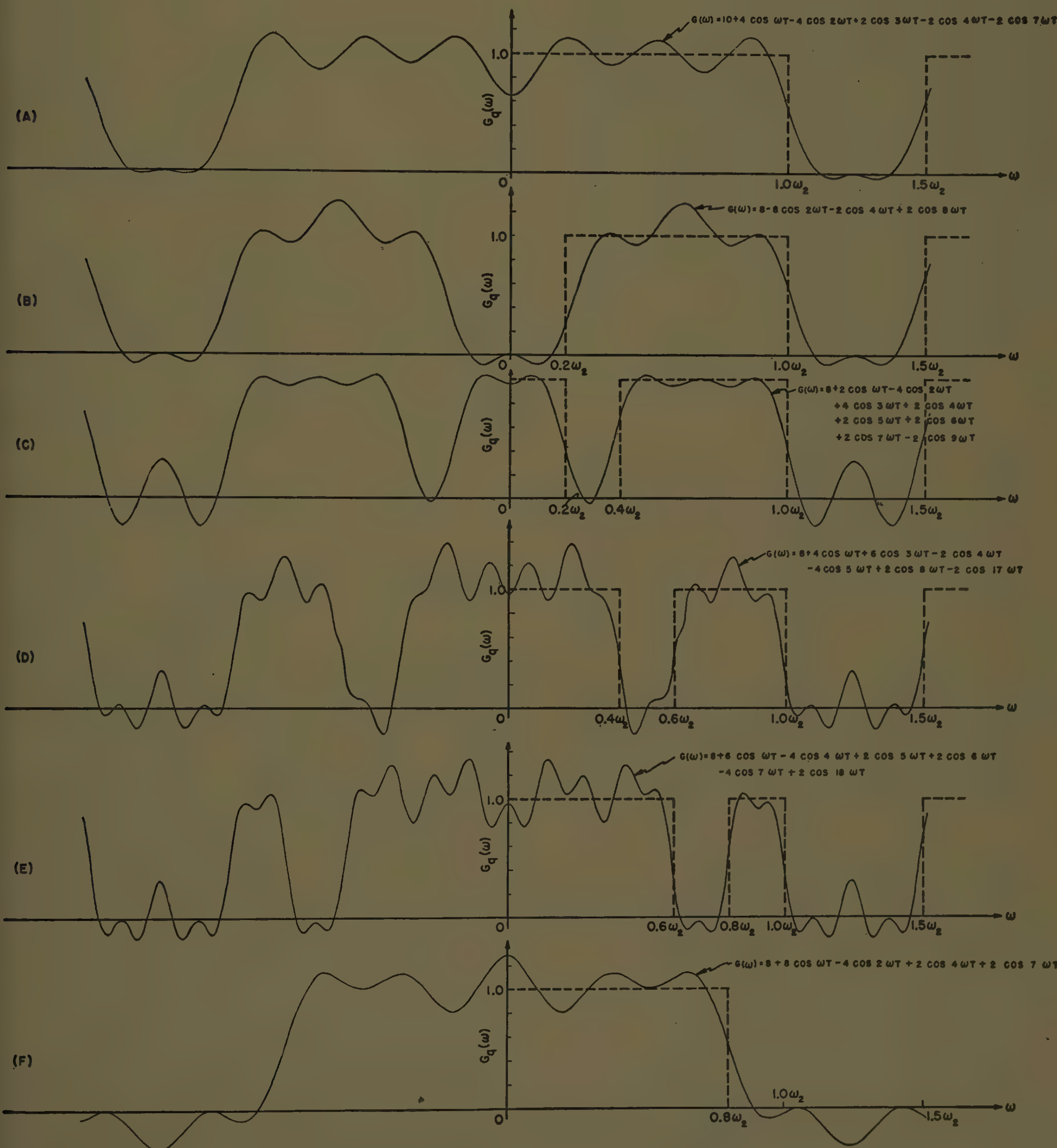

Figure 10. Effect of quantizing on modulating signal

infinite train of pulses, will be carried over to the analysis of PCM. However, the difference between the two processes of pulse amplitude modulation and PCM when applied to the time function $f(t)$ must be clearly understood. In the case of pulse amplitude modulation $G_2(\omega)$, equation 51 is the total contribution to the spectrum of an infinite number of pulses to produce a spectrum containing the original audio band (without distortion) plus the side bands distributed about the harmonics of ω_s. In PCM the modulated pulses are transmitted not with amplitudes proportional to $f(t)$ but with amplitudes equal to an integral number of amplitude levels, the nearest integral level to $f(t)$ being transmitted. In this case $G_2(\omega)$ will be modified by two causes: first, the fact that signals below a half a level are neglected thus rendering the number of modulated pulses finite, and second the process of quantization, that is the pulses transmitted are not truly proportional to $f(t)$ but are of integral value. The method of attack will be to reconstruct the new frequency spectrum $G_q(\omega)$ and to calculate the energy splashed over into the unoccupied channels in the process of PCM.

Calculation of Cross Talk in Individual Channels. Consider a modulating frequency band as shown in Figure 8. The transform of $g(\omega)$ is

$$f(t)=\frac{2A}{\sqrt{2\pi}}\int_0^\infty g(\omega)\cos\omega t\,dt$$

$$=\frac{2A}{\sqrt{2\pi}}\left[\frac{\sin\omega_2 t}{t}+\frac{\sin\omega_3 t}{t}-\frac{\sin\omega_4 t}{t}\right] \tag{56}$$

Let

$\Delta\omega=\alpha\omega_2$

where

$0<\alpha<1$

and

$\omega_g=\dfrac{\omega_3+\omega_4}{2}$

= center frequency of channel under consideration

Therefore

$$f(t)=\frac{2A\omega_2}{\sqrt{2\pi}}\left[\frac{\sin\omega_2 t}{\omega_2 t}-\alpha\left(\frac{\sin\dfrac{\Delta\omega\times t}{2}}{\dfrac{\Delta\omega\times t}{2}}\right)\cos\omega_g t\right] \tag{57}$$

It is important to note here that when α is very small this time function will vary only slightly from the original

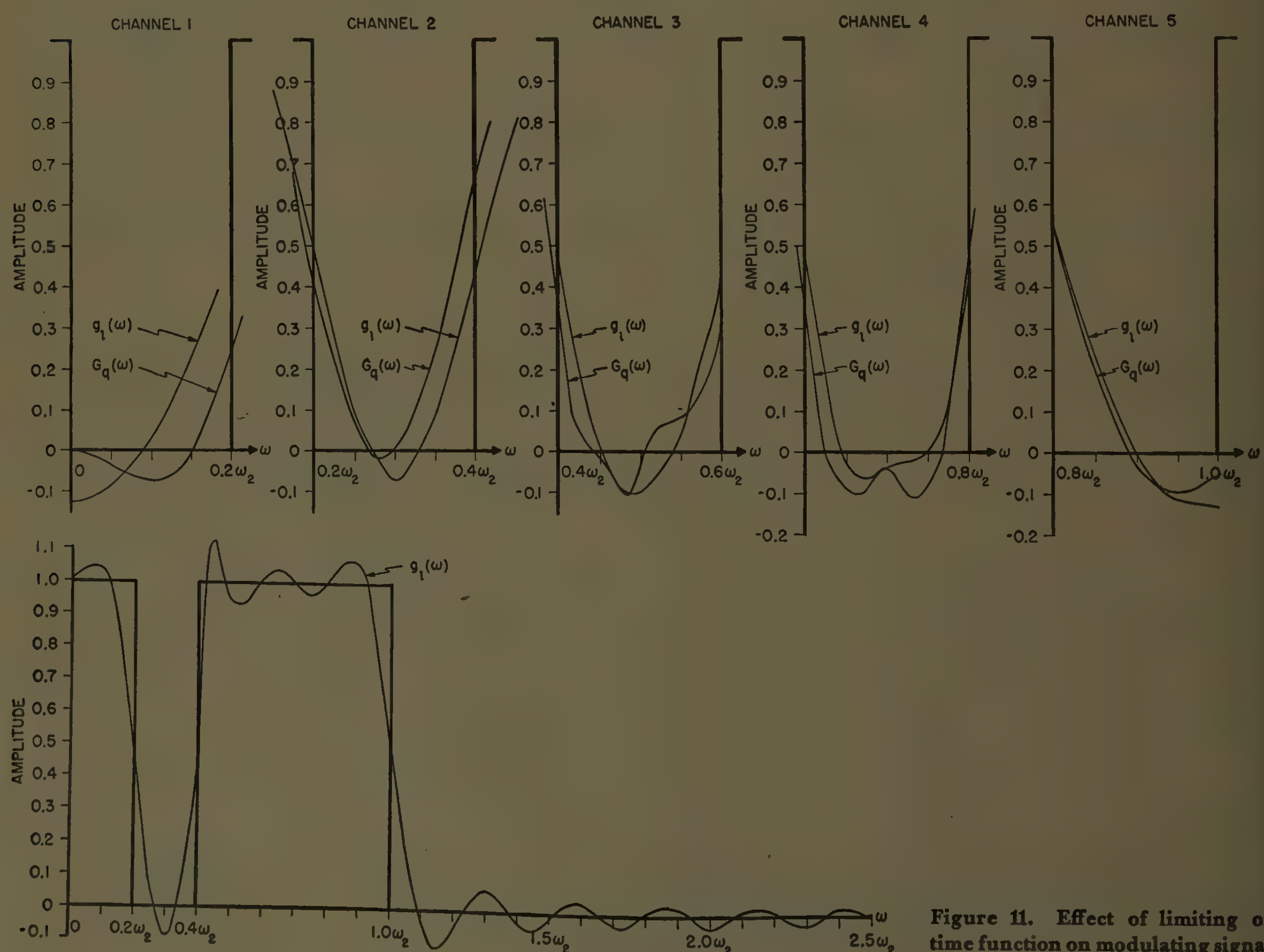

Figure 11. Effect of limiting of time function on modulating signal

one corresponding to a solid band 0–ω_2. As a result of this, the energy reflected in the narrow gap in the process of PCM will fill the gap completely, while in pulse amplitude modulation $g(\omega)$ is reproduced faithfully.

Returning to equation 57, the spectrum of the output in pulse amplitude modulation (see equation 51) would equal

$$G_2(\omega)=\frac{2A\tau\omega_2}{2\pi}\times\frac{\sin\frac{\omega\tau}{2}}{\omega\frac{\tau}{2}}\left\{(1-\alpha)+2\sum_{\nu=1}^{\infty}\times\left[\frac{\sin\omega_2\nu T}{\omega_2\nu T}-\alpha\left(\frac{\sin\frac{\Delta\omega\times\nu T}{2}}{\frac{\Delta\omega\times\nu T}{2}}\right)\times\cos\omega_a\nu T\right]\cos\nu T\omega\right\}$$

$$=AS_0(2Tf_2)\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\left\{(1-\alpha)+2\sum_{\nu=1}^{\infty}\times\left[\frac{\sin\omega_2\nu T}{\omega_2\nu T}-\alpha\left(\frac{\sin\frac{\Delta\omega\times\nu T}{2}}{\frac{\Delta\omega\times\nu T}{2}}\right)\times\cos\omega_a\nu T\right]\cos\nu T\omega\right\} \quad (58)$$

In the process of quantization the number of contributing pulses become finite and the corresponding frequency spectrum

$$G_q(\omega)=(AS_0)(2Tf_2)\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\times\left[(1-\alpha)+2\sum_{\nu=1}^{\nu=k}A\nu\cos\nu T\omega\right] \quad (59)$$

where k equals the number of pulses contributing to the transmission of the intelligence and A_ν equals the quantized value of $f(\nu T)$.

For a given number of levels m corresponding to $f(0)$ one can determine k for a particular case and the corresponding amplitudes. These data will enable one to calculate the energy in any channel in the band under consideration

Numerical Results. The method described is illustrated graphically in Figures 9 and 10. A frequency band of 0–20 kc with 4-kc channels and a scanning frequency of 50 kc are considered. Figure 9 illustrates the time functions corresponding to the different modulating signals, with the maximum amplitude of $f(t)$ in (A) corresponding to 10 levels, and the effect of quantization is illustrated clearly by the transmitted pulses. The corresponding frequency spectra $G_q(\omega)$ (equation 59) were reconstructed in Figure 10 where the spectra corresponding to pulse amplitude modulation also are superimposed for comparison. The energy appearing in each unoccupied channel equals

$$\int_{\omega_2}^{\omega_4} G_q(\omega)^2 d\omega$$

and the cross talk equals the square root of the ratio of this energy to the normal energy per channel. The results are shown in Table III.

It is significant that the cross talk varies greatly from channel to channel. Of course the number of levels is rather small and it is impossible to arrive at definite conclusions as to the relation between cross talk and number of levels.

Cross Talk Resulting From Limiting of Function. Let us further investigate the effect upon the cross talk arising from the fact that $f(t)$ is not scanned from $-\infty$ to $+\infty$ but between the limits $-t_0 \leqq t \leqq +t_0$. As explained in the introduction of this section, in the PCM system amplitude levels smaller than half a level are neglected which results in scanning a limited time function $f_l(t)$. While the transform of $f(t)$, equation 56, equal $g(\omega)$ of Figure 8, the transform of $f_l(t)$ will produce a modified spectrum denoted by $g_l(\omega)$, namely,

$$T_t^\omega f(t)=g(\omega)$$

$$T_t^\omega f_l(t)=g_l(\omega)$$

Applying pulse amplitude modulation to such a frequency band, output spectrum (equation 55) equals

$$G_l(\omega)=S_0\frac{\sin\omega\frac{\tau}{2}}{\omega\frac{\tau}{2}}\sum_{\nu=-\infty}^{+\infty}g_l(\omega-\nu\omega_s) \quad (60)$$

In order to determine $G_l(\omega)$ the function $g_l(\omega)$ must be found which is the transform of $f_l(t)$.

$$T_t^\omega f_l(t)=\frac{A}{\pi}\int_{-t_0}^{+t_0}\left[\frac{\sin\omega_2 t}{t}+\frac{\sin\omega_3 t}{t}-\frac{\sin\omega_4 t}{t}\right]\epsilon^{-j\omega t}\,dt$$

Therefore

$$g_l(\omega)=g(\omega)-\frac{2}{\sqrt{2\pi}}\int_{t_0}^{\infty}f(t)\cos\omega t\,dt \quad (61)$$

where t_0 is greater than zero. Equation 61 contains the contribution to cross talk due to limiting of $f(t)$ which is represented by the term

$$\frac{2}{\sqrt{2\pi}}\int_{t_0}^{\infty}f(t)\cos\omega t\,dt$$

Therefore

$$\frac{2}{\sqrt{2\pi}}\int_{t_0}^{\infty}f(t)\cos\omega t\,dt=\frac{2A}{\pi}\times\int_{t_0}^{\infty}\left(\frac{\sin\omega_2 t}{t}+\frac{\sin\omega_3 t}{t}-\frac{\sin\omega_4 t}{t}\right)\times\cos\omega t\,dt \quad (62)$$

or

$$g_l(\omega)=g(\omega)-\left\{\int_{t_0}^{\infty}\left[\frac{\sin(\omega_2+\omega)t}{t}+\frac{\sin(\omega_2-\omega)t}{t}\right]dt+\int_{t_0}^{\infty}\left[\frac{\sin(\omega_3+\omega)t}{t}+\frac{\sin(\omega_3-\omega)t}{t}\right]dt-\int_{t_0}^{\infty}\left[\frac{\sin(\omega_4+\omega)t}{t}+\frac{\sin(\omega_4-\omega)t}{t}\right]dt\right\}=g(\omega)-I_1-I_2+I_3 \quad (63)$$

Where I_1, I_2, and I_3 vary through the different regions of ω_2 as shown subsequently:

$0<\omega<\omega_3$.

$$I_1=\frac{A}{\pi}[\pi-S_i(\omega_2+\omega)t_0-S_i(\omega_2-\omega)t_0]$$

$$I_2=\frac{A}{\pi}[\pi-S_i(\omega_3+\omega)t_0-S_i(\omega_3-\omega)t_0]$$

$$I_3=\frac{A}{\pi}[\pi-S_i(\omega_4+\omega)t_0-S_i(\omega_4-\omega)t_0]$$

where

$$S_i(x)=\int_0^x\frac{\sin u}{u}du$$

$\omega_3<\omega<\omega_4$.

$$I_1=\frac{A}{\pi}[\omega-S_i(\omega_2+\omega)t_0-S_i(\omega_2-\omega)t_0]$$

$$I_2=\frac{A}{\pi}[-S_i(\omega_3+\omega)t_0+S_i(\omega-\omega_3)t_0]$$

$$I_3=\frac{A}{\pi}[\pi-S_i(\omega_4+\omega)t_0-S_i(\omega_4-\omega)t_0]$$

$\omega_4<\omega<\omega_2$.

$$I_1=\frac{A}{\pi}[\pi-S_i(\omega_2+\omega)t_0-S_i(\omega_2-\omega)t_0]$$

$$I_2=\frac{A}{\pi}[-S_i(\omega_3+\omega)t_0+S_i(\omega-\omega_3)t_0]$$

$$I_3=\frac{A}{\pi}[-S_i(\omega_4+\omega)t_0+S_i(\omega-\omega_4)t_0]$$

$\omega_2<\omega<\infty$.

$$I_1=\frac{A}{\pi}[-S_i(\omega_2+\omega)t_0+S_i(\omega-\omega_2)t_0]$$

$$I_2=\frac{A}{\pi}[-S_i(\omega_3+\omega)t_0+S_i(\omega-\omega_3)t_0]$$

$$I_3=\frac{A}{\pi}[-S_i(\omega_4+\omega)t_0+S_i(\omega-\omega_4)t_0]$$

A plot of $g_i(\omega)$ for a particular case is shown in Figure 11*F*. Note that $g_i(\omega)$ extends beyond ω_2.

During the process of pulse amplitude modulation, $g_i(\omega)$ will be reproduced without distortion at a reduced scale. However, the spectrum of $g_i(\omega_S-\omega)$ will overlap with the lowest audio band and thus introduce additional distortion in the gap which is indicated clearly in this figure.

Quantization of Limited Signal. The process of quantization may be expressed mathematically by modifying equation 46 as follows:

$$\varphi_0(t)\sum_{\nu=-\infty}^{+\infty}E_\nu[P_\tau(t-\nu T)+\xi_\tau(t-\nu T)] \tag{64}$$

where ξ_T represents the quantization of the nearest level.

Therefore

$$\varphi_0(t)=\sum_{\nu=-\infty}^{+\infty}E[P_T(t-\nu T)+\xi_T(t-\nu T)]+$$
$$\sum_{-\infty}^{+\infty}[f_i(t)\times\delta_0(t-\nu T)]P_T(t-\nu T)+$$
$$\sum_{-\infty}^{\infty}[f_i(t)\times\delta_0(t-\nu T)]\xi_T(t-\nu T)$$

By choosing the proper scale, the first term of $\varphi_g(t)$ may be adjusted to give zero. The second term equals

$$G_i(\omega)=S_0\frac{\sin\omega\frac{T}{2}}{\omega\frac{T}{2}}\sum_{\nu=-\infty}^{+\infty}g_i(\omega-\nu\omega_S)$$

which is equation (60), and the third term represents the contribution of quantization whose maximum effect seems to occur when $f_i(t)$ is distorted in the $+ve$ sense when $f_i(t)$ is $+ve$, and the $-ve$ sense when $f_i(t)$ is $-ve$. Also the maximum value of ξ_T equals $1/2m$ times the maximum amplitude of $f(t)$, m being number of levels contained in this maximum amplitude, so that the complete distortion spectrum becomes

$$[G_i(\omega)]_m=\left(1+\frac{1}{2m}\right)S_0\frac{\sin\omega\frac{T}{2}}{\omega\frac{T}{2}}\times\sum_{\nu=-\infty}^{+\infty}g_i(\omega-\nu\omega_S) \tag{65}$$

The important conclusion to be drawn from equation 65 is that when m is large, the main contribution to cross talk arises from the limiting of the function $f(t)$ in the process of quantization.

In practice m is large and the problem is simplified, greatly due to the fact that equation 63 may be used with some modification, since the main interest is in the channel $\omega_3<\omega<\omega_4$ only, where $g(\omega)=0$. The energy appearing in it will be due to I_1, I_2, and I_3 of equation 63 and proper consideration being given to the contribution of $g_i(\omega_S-\omega)$.

Figure 11 illustrates clearly that the main distortion is due to the limiting of the time function $f(t)$. The values of $G_g(\omega)$ of Figure 10 are superimposed here for comparison with $g_i(\omega)$. Where the distortion is small and the contribution of the factor $1/2m$ of equation 65 is comparable to it, the two curves vary. Hence, the following procedure may be outlined for the determination of the distortion in a particular channel:

1. Determine the time function $f(t)$ corresponding to the modulating signal (equation 56).

2. For a given number of levels m determine t_0 which represents the time of last significant pulse to be transmitted in the time function $f(t)$.

3. Calculate $g_i(\omega)$ (equation 63) from which the energy in the channel may be obtained.

PCM Equipment

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PCM, pulse code modulation, is a new solution to the problem of overcrowded frequency spectrum. It appears to have exceptional possibilities from the standpoint of freedom from interference, and seems to have inherent advantages over other types of multiplexing.

THE methods of transmitting intelligence by means of short bursts or pulses of energy have shown increasing application within recent years. Such applications have included radio relay systems, telephone multiplex, telemetering, and multiplex broadcasting, all of which have been described in the technical literature. Pulse modulation exhibits many important characteristics which makes the method particularly applicable to communication transmission systems. One of the fundamental properties is the ease of transmitting more than one intelligence signal through multiplexing by means of time division. With this method the increments of each modulating signal are interleaved in time sequence and, since only one increment is transmitted at any one instant of time, nonlinearities in the transmission system do not introduce interchannel cross talk products such as would be obtained in the more conventional frequency division multiplex. Another characteristic is the noise reducing properties obtained as a function of the transmission band width utilized. A third factor obtained with pulse systems utilizing constant amplitude pulses is the corresponding constant amplitude transmission characteristic which permits the system to be independent of fading and other transmission vagaries. A further important property is the flexibility of the pulse function which allows the various transmission constants to be interchanged, that is, band width for signal-to-noise ratio, distortion and cross talk for band width, number of channels for signal-to-noise ratio or band width and other combinations, thus permitting a system design directly suited to the specific application.

The conversion of the voice wave into coded pulses involves two principles, sampling and quantizing.

Sampling Principle. The sampling principle states: if a signal is sampled instantaneously at regular intervals and at a rate slightly higher than twice the highest signal frequency, then the samples contain all of the information of the original signal. This means, if a nonperiodic voice wave is plotted, it can be reproduced in all its detail from the values of a set of ordinates erected at equally spaced intervals provided the spacing of the sampling ordinates is less than half the period of the highest frequency component of the original wave.

Application of the sampling principle reduces the problem to one of sending a finite number of bits of information giving the magnitudes of the samples of the voice wave. However, this step alone does not permit translation to code because the possible magnitudes of these samples may, and generally will, occupy a continuous range of values. This difficulty is resolved by a second step, the application of the quantizing principle.

Quantizing Principle. The quantizing principle states: each of a set of small ranges into which a larger range may be divided is assigned a single discrete number. This number may be that corresponding to the mean of the range. For example, any value from minus 0.5 to plus 0.5 would be called zero, or a value between 94.5 and 95.5 would be called 95. It is quite apparent that some distortion or granularity is inherent in the application of the principle of quantization to samples of an electric signal carrying the information of the spoken word. The greater the size of the range assigned to a given character, and the fewer characters used, the greater will be this granularity. The problem is to determine the smallest number of steps into which voice signals may be quantized without serious distortion, and what the size of each step should be.

It has been found that application of the sampling principle permits the reduction of a continuous signal to 8,000 discrete samples per second, and application of the quantizing principle, provided logarithmic steps are used, permits each sample to be represented with sufficient accuracy by a code character which uses one of the various combinations of five to seven on-or-off pulses.

METHOD OF OPERATION

PCM Transmitter. In the PCM (pulse code modulation) transmitter (Figure 1) the timing of all operations is fixed by a 320-kc crystal-controlled oscillator. In the diagram of Figure 1, this oscillator and a 5-stage and 8-stage ring counter are included within the block designated "oscillator and pulse generators." The output of the oscillator is coupled to the 5-stage ring counter which divides the input frequency by five, producing in each stage of the counter 64,000 output pulses per second. Pulses in the output of a particu-

Essential substance of paper **47-131**, "Pulse Code Modulation," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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lar stage are coupled to another ring counter which has eight stages and there produce pulses in each stage at the rate of eight thousand per second or every 125 microseconds. Each stage in the 8-stage ring counter produces pulses of $15^5/_8$ microseconds duration at 125 microsecond intervals and, at any instant, one and only one stage is producing a pulse.

Each voice signal passes through a low-pass filter to a sampler. Each sampler also receives pulses from a particular stage of the 8-stage ring counter. The sampler is designed to deliver pulses whose magnitude is determined by the voice signal and whose time of occurrence is coincident with that of the applied pulses from the ring counter. When a voice signal is applied to any channel input, corresponding positive or negative pulses (samples of the voice signal) appear in the time intervals assigned to that channel. The output from the samplers is a type of signal known as pulse amplitude modulation.

The coder is designed to operate from length-modulated pulses. The output of the samplers, therefore, needs to be converted from pulse amplitude modulation to pulse length modulation and this is done in a converter.

In the converter, a capacitor is charged to a magnitude controlled by the amplitude-modulated pulse. The time required for the capacitor to discharge to a specified voltage is proportional to its charge. The discharge current generates length-modulated pulses. The leading edges of these pulses, which are represented by the discharge current, recur at regular intervals.

These length-modulated pulses are used to turn on an amplifier. This amplifier, designated "gate", consists of a twin tube whose grids are driven in push-pull by a 1,600-kc sine wave, obtained by generating the fifth harmonic of the 320-kc oscillations. The plates of the tubes are coupled to the first stage of the binary counter and deliver short pulses (pips) at a rate of 3,200,000 per second for the duration of each the length-modulated pulses. These short pulses are counted.

Each stage of the 5-stage binary counter consists of two tubes, one of which may be called the odd tube and one the even tube. The circuit is designed so that when either tube conducts, the other does not. Thus, the application of a pulse causes a stage to reverse its position and assume the opposite state regardless of which state it was in. For example, if the even tube is conducting and the odd tube is not, the application of the next pulse causes the even tube to become nonconducting and the odd tube conducting. Coupling between stages is such that a pulse is applied to a succeeding stage only when the even tube of the previous stage is made to conduct. Knowledge of the condition of conduction of either of the tubes tells whether an even or odd number of pulses has been applied to that particular stage.

At the end of the counting interval, to discover how many pulses have been counted, it is sufficient to examine the odd tubes. If the odd tube of the first stage is found conducting, we write down 1 and if nonconducting, 0. If the odd tube of the second stage is conducting, the number recorded is 2 and if nonconducting, 0. Similarly, for the remaining three stages we write 4 or 0, 8 or 0, and 16 or 0, respectively. The number of pulses counted equals the sum of the five numbers obtained in this way. The maximum change in length of the length-modulated pulse controlling the gate is such that counts from 0 to 31 are possible. With no input to a channel, a count of 15 or 16 is equally probable.

Application of a reset pulse to the counter forces all of the even tubes to conduct, thereby cutting off plate current to the odd tubes. Removal of the reset pulse releases the counter which is then in a condition to count the next series of pulses.

Following each counting period and preceding the reset pulse, the condition of the counter is transmitted to the PCM receiver by sending in succession an on-or-off pulse for each counter stage depending upon whether the odd tube is conducting or nonconducting. The first on-or-off pulse is transmitted under the direct control of the first counter stage. The data from the remaining stages are stored. This is accomplished by charging capacitors, called storage capacitors, under control of the counter stages. Gate tubes acting as amplifiers are coupled to the storage capacitors and are pulsed (turned on) in successive intervals and do or do not deliver pulses as indicated by the condition of each counter stage.

As these pulses from the coder are not uniform in shape or duration, they are applied to a pulse shaper. This pulse shaper consists of a gate, opened or closed by the coder output, and fed by short pulses which recur uniformly at a 320-kc rate. By this means the coder pulses control the release to the line of pulses of uniform amplitude and duration.

Synchronization. In order that the eight channels may be separated, it is necessary that the receiver gates

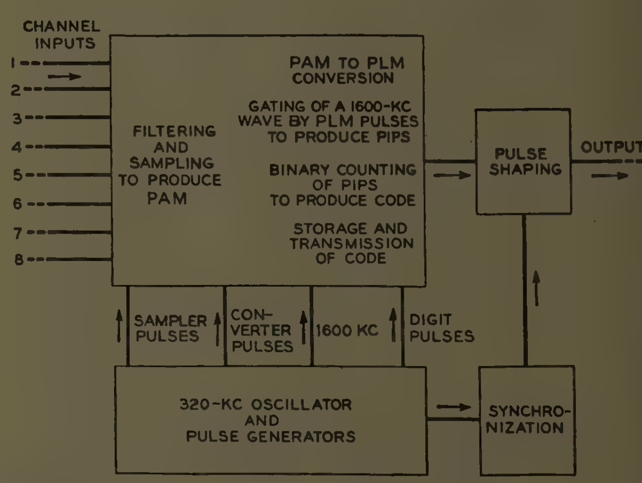

Figure 1. Functional diagram of PCM transmitter

should receive pulses of exactly the right frequency and in the correct time relation. The transmitted signal contains a prominent 320-kc component which is selected by tuned amplifiers and limiters to produce a steady 320-kc wave. Suitable gate pulses are produced by dividing this frequency by five and then eight. After division by 40, there are 40 possible time relations between these gate pulses and the corresponding signals from the transmitter, only one of which results in correctly separating the coded signals and routing them to the desired channels. This uncertainty must be resolved by the transmission of a frame marker or other appropriate identification.

In the PCM receiver, the "synchronizing control circuit" selects the frame marker pulses and prominent 320-kc sine wave which are used to lock the "oscillator and pulse generators" in their required time relation with respect to the received pulse array.

ABSTRACTS... OF AIEE TECHNICAL PROGRAM PAPERS

TECHNICAL PAPERS previewed in this section will be presented at the AIEE Midwest general meeting, Chicago, Ill., November 3–7, 1947, and will be distributed in advance pamphlet form as soon as they become available. Members may obtain copies by mail from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstracts; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk. Prices of copies to nonmembers will be twice those for members, less five cents for mailed copies.

MAIL ORDERS will be filled as pamphlets become available.

ABSTRACTS are prepared by the authors of the papers and approved by the technical program committee.

Basic Sciences

47-265—Determination of Corona Starting Voltages for Nonuniform Fields in Air; *John G. Hutton (M'46). 35 cents.* Until recently sparkover and corona starting voltages only could be predetermined satisfactorily in cases where experimental curves or empirical formulas were available. The advent of the Townsend theory, and later its modification, led to a general method in breakdown calculations, although these were not entirely successful until a more complete knowledge of the Townsend coefficients for air was obtained. Based upon this knowledge, and from published data, Ver Planck developed a method especially applicable for calculating initial breakdown voltages for nonuniform fields which converge toward the cathode. Though still empirical the increased data enabled more accurate results to be obtained from this method. The purpose of this paper is to apply the theory to a case where the field is produced between a flat plate and an edge formed by two intersecting planes and to verify the calculations experimentally.

47-266—Diffusion of Electric Current into Rods, Tubes, and Flat Surfaces; *K. W. Miller (M'29). 30 cents.* Electric current density penetrates or "soaks" into an electric conductor from the surface during current transients in a manner physically and mathematically analogous to thermal diffusion in transient heat flow. This useful concept is used to explain physically and numerically evaluate transient resistance and inductance of conductors subjected to rectangular current wave impulses.

Communications

47-256—General Mobile Telephone System; *H. I. Romnes (A'41), R. R. O'Connor (M'43). 25 cents.* In a little more than a year since the first general mobile radiotelephone service was established in St. Louis, the service has been made available in more than 60 cities throughout the United States. A typical system employs a 250-watt frequency modulation transmitter and fixed receivers, serves 50 to 100 vehicles within a radius of 15 to 30 miles, and is tied into the general telephone network through a control terminal and switchboard. In order to provide a reliable and interference-free service, many refinements are necessary in the radio and associated equipment, particularly when many mobile radio channels are to be operated in an area. Some of these refinements and the outlook for the future are discussed in the paper.

47-258—Frequency Division Techniques for a Coaxial Cable Network; *R. E. Crane (M'36), J. T. Dixon (A'39), G. H. Huber (M'39). 35 cents.* A description is given of developments employing frequency division techniques by means of which the telephone message carrying potentialities of the coaxial cable system are realized. The extension of the frequency range of multichannel modulators up to 3,000 kc is described. A method of accurate control of frequencies in this range is discussed. The complexity of problems involved in transmitting a very large group of circuits over a single path are outlined. Arrangements are described by means of which 480 long-haul and 120 short-haul telephone circuits are provided over a single coaxial in each direction. At intermediate points appropriate groups of channels may be removed, inserted, bridged, or relocated in the frequency spectrum of the line.

Electronics

47-264—Ignitor Characteristics and Circuit Calculations; *D. E. Marshall (M'33). 25 cents.* The paper proposes a method of presenting the characteristics of pool tube ignitors of the resistance type and indicates a method of using the data in calculating the performance of the ignitor. Characteristics of a typical ignitor are given, and two examples of circuit performance calculations are worked out.

Industrial Power Systems

47-249-ACO—First Interim Report on Interior Wiring Design for Commercial Buildings; *Subcommittee on Interior Wiring Design for Commercial Buildings of the Industrial Power Systems Committee.* 40 cents. This report presents the outline of a method or procedure for the application of sound engineering principles to the design of interior wiring systems for commercial buildings. It stipulates the type of detailed information that must be assembled and further, indicates how that information should be employed to arrive at the design of a wiring system which will be entirely adequate for the present and reasonably adequate for the future. The report is not meant to be a wiring code and is not intended to serve as a wiring specification to supplant the electrical engineer's vital work in analyzing the particular wiring design of a specific building. Its purpose is to present to the

engineer, the architect, and building owner a sound and logical method for dealing with the involved question of the design of interior wiring systems for commercial buildings. Examples of several chapters of the proposed report are included for discussion.

Industrial Controls

47-251—A Control System for Wind Tunnel Drives; *A. H. Heidenreich* (*F'27*). *25 cents.* This paper is of particular interest to those engaged in the aeronautical branch of engineering. It provides a description of the manner in which the drives for the majority of the large wind tunnels function, together with details of precision speed control, constant reference voltage, antihunt provisions, power factor control, pump-back or return of energy to the supply system, initial inrush, and data for selection of drives for particular tunnel applications. The paper uses as an example the drive system of the altitude wind tunnel of the Cleveland laboratory of the National Advisory Committee for Aeronautics.

Power Generation

47-248—Generating Reserve Capacity Determined by the Probability Method; *Giuseppe Calabrese* (*M'40*). *40 cents.* A fundamental problem in system planning is the determination of reserve capacity. Too low a value means excessive interruptions, while too high a value results in excessive costs. The greater the uncertainty regarding the actual reliability of any installation, the greater the wasted investment required. In the typical case of system generating capacity reserve the problem not only concerns the risk of outage but also the economic balance between generator reserve and the capacity in providing against local outage concentration. The complexity of the problem, in general, makes it difficult to find an answer by rules of thumb. The same complexity, on one side, and good engineering and sound economics on the other, justify the use of methods of analysis permitting the systematic evaluation of all important factors. It is the purpose of this paper to describe a method of determining reserve capacity based on the probability theory. This method was evolved some ten years ago in an attempt at rationalizing the reserve practice of the company with which the author is affiliated. Briefly, the method proceeds from the assumption that forced outages of units are random events, independent from one another, and that outage durations of units can be calculated by the well-known binomial expansion. Starting from the above assumption, the paper deals first with the determination, of the forced outage rate of individual units which is the basic quantity of the method. Formulas and tables are given next, for calculating the probability of outage of various outage combinations. These are followed by a check of the assumed independence of individual unit outages. Methods are developed for calculating probability of outages and of loss of load for a given system, taking into consideration the effect of interconnections with other systems. These probabilities of outages and of loss of load may be used as indexes of service reliability for determining reserve requirements. Other indexes of service reliability can be obtained by calculating, from these probabilities, the expected kilowatt-hour losses per kilowatt of installed capacity, or of maximum load.

47-250—Progress in Power Generation—1940–46; *AIEE Committee Report. 40 cents.* Many innovations and extended developments of new and proved methods of energy production have taken place over the past seven years. Higher pressures and temperatures have found increasing commercial application in steam-turbine plants, new high levels in temperature are projected, record size hydroelectric plants continue to be installed, intensive experimentation and a few commercial installations mark gas-turbine development, a wind turbine supplied a-c energy for a time into a utility system. Outstanding achievement of wartime technical activities was the release of atomic energy with its promising possibilities for large-scale energy production in the future. Accessory apparatus also has undergone improvement in respect to increased ratings and better utilization of materials. History and continued expansion of energy demand is discussed. A very extensive bibliography is a feature of the report.

47-252—Calculating Probability of Generating Capacity Outages; *W. J. Lyman* (*F'43*). *30 cents.* The subject of generating station capacity outages has been receiving an increasing amount of attention and the use of probability calculations to facilitate these studies has been steadily gaining ground, not only for determining the proper amount of reserve capacity, but also in analyzing the effectiveness of interconnections, and for studying other important problems. Generator outage probability calculations are usually complex and time consuming, and the purpose of this paper is to present several methods which have been developed to obtain approximate solutions sufficiently accurate to have many uses. This paper includes

1. A short-cut method applicable to a system with any number of generating units of different sizes.
2. Equivalent failure rates for different types of turbine and boiler layouts.
3. Method of combining two or more outage probability curves for different systems.
4. Effect on system outage probability curve of adding a generating unit.

47-253—Outage Expectancy as a Basis for Generator Reserve; *H. P. Seelye* (*F'43*). *20 cents.* Probability calculations furnish a useful means whereby the average frequency and duration of generator outages on a power system, as shown by experience records, may be converted into a consistent measure of the expectancy of multiple outages upon which the provision of reserves is based. This paper gives the mathematical development of relatively simple formulas for this purpose and methods of calculation and of exhibiting the results in tangible form. Use of these formulas does not require familiarity with technical probability mathematics.

47-254—Probability Methods Applied to Generating Capacity Problems of a Combined Hydro and Steam System; *E. S. Loane, C. W. Watchorn* (*A'29*). *30 cents.* This paper illustrates an arithmetical solution of various generating capacity problems. It gives proper recognition, within practical limits, to all the pertinent factors relating to such problems, namely: the number, size, and location of units; routine and scheduled maintenance requirements and seasonal capacity reductions of the system generating capacity; and the relation of these factors to the varying magnitude of the system loads throughout the year. The reductions in the load carrying capability of the system hydro plants are based on a long record of river flow experience related chronologically to the system load, so as properly to appraise the effects of the variations in river flow as chance events. A brief description is given of a synthetic forced outage study of the characteristics of coincident forced outages of large amounts of steam capacity of an actual system for a 100-year period. This study was the basis for evaluating the probable use of additional hydro storage over that required for normal operation.

47-259—Suddenly Applied Loads on a Variable-Ratio Frequency Changer; *C. K. Carter* (*M'43*), *F. J. Maginniss* (*A'43*), *F. S. Rothe* (*A'36*). *30 cents.* This paper presents the results of a study of the load-current and voltage variation following the sudden application of an impedance load to the terminals of a previously unloaded variable-ratio slip-frequency-excited frequency-changer set, including the case of sudden 3-phase and single-phase short circuits. The maximum load under which voltage may be sustained is determined for various conditions, as well as the rates of decay which may be expected in those cases wherein voltage is not sustained. The study was made on the differential analyzer and uses the analysis developed in the companion paper by G. Kron (47-260).

47-260—Tensorial Analysis and Equivalent Circuit of a Variable-Ratio Frequency Changer; *Gabriel Kron* (*M'45*). *25 cents.* When two power systems with different frequencies are connected together through an asynchronous tie the transient behavior of the tie under a sudden change of load on either side becomes of great importance. The paper derives, by the tensorial method, the steady-state equivalent circuit and the transient equations of a variable-ratio frequency-changer set consisting of an ohmic-drop exciter, Scherbius regulator, and induction machine, when an unbalanced load

suddenly is applied to the stator side of the induction machine. A companion paper by Carter, Maginniss, and Rothe gives the results of the solution of the equations by the a-c network analyzer and the differential analyzer (47-259).

47-261—Resynchronizing of Generators; *C. Concordia (M'37), M. Temoshok. 30 cents.* This paper presents data on the performance of synchronous generators during out-of-step operation as occasioned by loss of field excitation or by severe faults. Two aspects have been studied with the aid of the differential analyzer, first, the system and machine characteristics affecting the possibility of spontaneous resynchronization, and second, the machine behavior (particularly its effective impedance) when it is out-of-step and during resynchronizing.

Protective Devices

47-237—Present-Day Grounding Practices on Power Systems, Third AIEE Report on Grounding Practices; *AIEE Subject Committee on Present-Day Grounding Practices. 40 cents.* The committee has prepared this report on the grounding practices of power systems from replies to questionnaires submitted to those electrical utilities, both public and private, in the United States and Canada, having a generating capacity of more than 10,000 kw, or having more than 10,000 customers. The report covers separately grounding practices on 460 generating station systems (at 11 kv and above) and 567 transmission and distribution systems (at 22 kv and above). There are 972 generating units and 119,081 miles of transmission circuits, embodied in the report. The ratio of phase-to-ground to 3-phase fault currents and the sequence-impedance ratios, as well as principal characteristics of the grounding devices used, are tabulated. Opinions of the utilities as to the importance of 16 different factors in the grounding problem as applied to their systems, as well as assigned reasons for their specific practice, have been included.

Rotating Machinery

47-262—Two-Stage Rototrol for Low Energy Regulating Systems; *A. W. Kimball. 25 cents.* The fundamental principles of operation and application of Rototrols have been discussed in a number of papers and publications. These have dealt with a unit having only one stage of amplification of the control energy. Such machines have been applied widely during the last 15 years with excellent results. Recently a few applications have arisen in which the control energy available was too small to provide satisfactory regulation. The use of a second unit operating as a control energy amplifier then was needed. The development of the 2-stage Rototrol permits the use of only one machine in such applications. The simplest construction of this machine is a 4-pole design. It is a normal generator except for the field coils and armature connections. With such modifications this paper shows that the machine may be considered as three generators superimposed on one another. The output of only two of these is used in the machine under consideration. The analysis of operation and means of compensation for the resulting reactions are given. Tests of two designs show that high sensitivity and speed of response were obtained. It is concluded that the development of this machine provided a generating element for Rototrol systems which requires an extremely low value of control energy.

47-263—The Circle Diagram of the Polyphase Brush Shifting Commutator Motor (Schrage Type); *Paul W. Franklin (A'39). 25 cents.* The polyphase brush shifting commutator motor (shunt type) may be considered as a normal 2-element induction motor, equipped with a frequency and voltage transforming device which inserts an extra voltage into the secondary circuit. In the case of the Schrage motor, the primary winding is located in the rotor and the transforming device consists of an additional d-c type winding and a commutator with adjustable brushes. The secondary winding, located in the stator, is double-fed electromagnetically through the air gap and conductively by the brushes. Depending upon the brush position, additional energy may flow to and from the secondary member, together with a corresponding change of speed above and below the synchronous point. For this machine a representative circuit and a circle diagram is derived and discussed. The formulas presented are applicable to design work.

Switchgear

47-239—The Application of Storage Batteries to the Control of Switchgear; *E. A. Hoxie (A'45). 35 cents.* For many years storage batteries have been used as a source of energy for the operation of switchgear. Nominally rated 125-volt control batteries usually have been selected so as to have sufficient capacity to provide the maximum momentary current at a minimum battery voltage of 105, which was adequate to conform to the requirements of closing mechanisms operating over the standard range of 90 to 130 volts. However, the need of additional power from the closing mechanism of some circuit breakers under abnormal or fault conditions has been apparent for some time. In considering ways and means of providing this additional power it is apparent that the performance of the storage battery under the conditions existing in this service must receive careful consideration. This paper presents detailed test results and information which the author hopes will be of assistance in determining the method to be used to obtain satisfactory circuit breaker closure under all conditions.

47-240—Gaseous Insulation for High-Voltage Apparatus; *G. Camilli (F'43), J. J. Chapman (A'40). 25 cents.* Compressed gases have been rather slow in finding application in high-voltage apparatus. To compete with liquid insulation, until recently such apparatus were operated at relatively high pressures (higher than 60 pounds per square inch). Furthermore, due to the low vapor pressure of the available gases, their inherent dielectric strength (at normal operating temperatures) could not be maintained easily at low ambient temperatures. A fluorinated sulphur compound is now available which seems to overcome these two major objections. Impulse and 60-cycle breakdown tests performed on a group of halogenated compounds in uniform and nonuniform fields indicate that sulphur hexafluoride has superior qualities over the Freons. Thus, in uniform dielectric fields the impulse strength of this gas (when tested between bare electrodes) increases consistently with pressure and at 30 pounds gauge pressure approaches the impulse strength of oil. Therefore, certain classes of high-voltage apparatus advantageously may use this gas for their insulation if other properties are adequate.

47-246—Switchgear Equipment for Tidd High-Voltage Test Line; *F. A. Lane (M'31), B. W. Wyman (M'46). 20 cents.* To assist in the investigation of the problems associated with higher transmission voltages, the General Electric Company has determined a suitable type of switching equipment and has developed a unit of this type to obtain experimental data on the Tidd high-voltage project of the American Gas and Electric Service Corporation. The equipment utilizes a power circuit breaker of the low oil content impulse type because of its excellent high-voltage performance characteristics and the successful field experience with the 287-kv Boulder Dam line breakers. A new concept in switching equipment units is advanced since this is a compact integrated unit including the circuit breaker, disconnecting switches, current transformers, interlocks, protective lightning arresters, and supporting structure with provisions for mounting of coupling capacitors for carrier-current equipment, relays, and similar associated equipment. It is expected that this concept, which is not necessarily limited to unusually high voltages, will effect great economies in space and cost.

Transformers

47-255—Transient Voltage Rise in Transformers Due to Interruption of Exciting Current; *A. Srinivasan (A'47), F. J. Vogel (M'41). 20 cents.* High voltages in a transformer installation led to an investigation of their origin. It was found that in this case at least, the interruption of the current could be forced at various points on the wave. In other words, interruption of magnetizing currents is not always at their normal current zero. In this case, the energy stored in the transformer core, less

hysteresis and eddy current losses, charged the transformer capacitance. From the source, it is concluded that switching surges of this type would be distributed uniformly in the winding. Concentration of voltage stress would occur only in case of terminal or other flashover.

Transmission and Distribution

47-238—Switching High-Voltage Transmission Lines; *I. B. Johnson (M'45), J. R. Wilson. 35 cents.* Voltage arresters provide the basis for rational reductions in insulation of terminal equipment on high-voltage transmission systems whereby appreciable economic advantages may be realized. Arrester operations by transient voltages result from lightning surges or switching surges. From a study of a system in miniature, it is the purpose of this paper to present information on the severity of switching surges with regard to voltage magnitude and duration, and arrester protection and duty that could be experienced on a future transmission system of greater length and operating at higher voltage levels than the present-day maximum. It is shown that the severity of switching surges is reduced by line sectionalizing, switching on the low-voltage side of transformers, and using circuit breakers with a minimum tendency to restrike. It is indicated that the severity of switching surge discharges through an arrester is of equal if not of primary importance as compared with expected lightning surge discharges.

47-241—Transmission of Electric Power at Extra High Voltages; *Philip Sporn (F'30), A. C. Monteith (F'45). 25 cents.* This is the introductory paper of the symposium pertaining to the tests being made at the Tidd power station of The Ohio Power Company to determine corona characteristics of conductors at voltages up to 500 kv. The two factors that influence design, and, therefore, costs of extra-high voltage transmission lines and systems, are corona and basic insulation level, and the two are interrelated. There is good engineering reason for the belief that materially lower insulation levels than any heretofore attempted on extra-high voltage transmission can be used successfully in the future, if all the unknown engineering questions that this raises can be answered. A specific series of such levels is presented in the paper. Of the questions that need to be answered, fairly good engineering data are now available on lightning and switching surges, insulation co-ordination, and the effects of line spacing on reactance and capacitance. But line spacing also affects corona. Some data are available on corona and radio influence, particularly on fair-weather corona losses for horizontal configuration on single conductor per phase and on how the surface affects these losses. There is need for corona-loss and radio-influence data showing the effect of ground wires on various combinations with single conductors and the effect of rain, fog, clouds, and other natural elements that make up the yearly weather conditions in a given location. Also, bundle conductors offer some advantages that need be investigated carefully to make possible proper weighing of advantages versus disadvantages. Such data would allow a closer estimate of corona losses so that they could be considered on an average loading basis, the same as other variable losses. All of this should lead to more precise design and the development of transmission systems operating at extra-high voltages that would yield the maximum economies possible by higher voltage use. The investigation and test program now in progress at the Tidd plant of The Ohio Power Company is planned to obtain the necessary data to answer these and other pertinent questions that need be answered to make possible the economic design of extra-high voltage transmission systems.

47-242—Corona Considerations on High-Voltage Lines and Design Features of Tidd 500-Kv Test Lines; *C. F. Wagner (F'40), Anthony Wagner, E. L. Peterson (M'31), I. W. Gross (F'45). 25 cents.* This paper is one of the papers comprising the symposium describing the tests being made at the Tidd power station of the American Gas and Electric Company to determine the corona characteristics of conductors at voltages up to 500 kv. The paper (1) reviews the present knowledge concerning corona, (2) describes the general features of the test setup and apparatus available, (3) describes in detail the towers and busses and the conditions for which they were designed and built, and (4) discusses the general objectives of the tests including the factors that will be varied. Two $1^{1}/_{2}$-mile lines and a third only one span in length have been constructed for test purposes. Corona power loss and radio influence will be determined for different line voltages, different spacings with and without ground wires under the wide range of weather conditions in southeastern Ohio. The influence of towers will be included in the test results.

47-243—Insulators and Line Hardware—Tidd 500-Kv Test Lines; *I. W. Gross (F'45), R. L. McCoy (M'43), J. M. Sheadel (A'39). 35 cents.* The factors considered in selecting and testing insulators for the 500-kv experimental test lines on the American Gas and Electric Company system are presented and test data given on the insulator strings used. Insulators of $5^{3}/_{4}$-inch spacing are used in string lengths of 26 to 30 units in single suspension and double this number in dead-end. A special new type suspension clamp is described in some detail. Data on the corona tests made on long strings of insulators for this test project are given. The designs of corona shields used on suspension and dead-end insulators are given, together with test data on their performance in the laboratory.

47-244—Line Conductors—Tidd 500-Kv Test Lines; *E. L. Peterson (M'31), D. M. Simmons (F'28), L. F Hickernell. (F'34), M. E. Noyes (M'30). 30 cents.* A description of the line conductors supplied for the 500-kv test lines on the American Gas and Electric Company's system at the Tidd plant at Brilliant, Ohio, is given. Various factors entering into the selection of conductors are discussed. The necessity of large outside diameter for single conductors on high-voltage transmission has made it necessary to go to larger conductor diameters with special features introduced in some cases. Single conductors of 1.4, 1.65, and 2.0-inch outside diameter will be used; also, the so-called "bundle" conductor will be tested for corona characteristics. Factors involved in selecting "bundle" conductors for trial test are described in detail.

47-245—Power Equipment—Tidd 500-Kv Test Line; *F. A. Lane (M'31), P. L. Bellaschi (F'40), J. K. Hodnetts (F'42), Edward Beck (M'35). 20 cents.* This paper is part of the symposium of papers dealing with 500-kv test lines at the Tidd plant of The Ohio Power Company at Brilliant, Ohio. The paper describes the power supply equipment required to energize the lines. The apparatus consists of a bank of three single-phase power transformers protected by lightning arresters and designed for operation in the field of extra-high voltages. The general approach to the problem of the design and the construction of the equipment is discussed in the paper. The economic advantages of grounding solidly the neutral are pointed out and data are given showing the relation between basic impulse levels and transformer prices. Estimated relative prices of arresters also are given. The transformers for the 500-kv test line were designed and manufactured in accordance with the basic principles used in the design and manufacture of commercial high-voltage transformers. Lightning arresters are an important factor in the consideration of reduced insulation classes. The lightning arresters adjacent to the transformers were designed with ratings of 70 per cent of the 500-kv maximum voltage line to line. Provision is made for reducing the arrester rating when line voltage is less than 500 kv.

47-247—Instrumentation and Measurement Tidd 500-Kv Test Lines; *R. L. Tremaine, G. D. Lippert (M'46). 30 cents.* This paper describes the instrumentation and measurement used on the Tidd 500-kv test lines Instrumentation is provided to measure corona loss, associated radio influence, and atmospheric conditions. Corona loss is measured by wattmeters which are mounted on top of the high-voltage bushings of the power transformers. The line charging current is passed through the current coil, and potential for the wattmeter is supplied by an extension of the high-voltage winding. The wattmeter used is a special "null" type meter of extremely high sensitivity. If the voltage coil of the wattmeter were connected directly across the extension winding, the current through it would not be in phase with the line-to-neutral voltage by an angle made up of three components. Individual corrections which vary automatically are made for each component of the error angle. The method of correction used results in very accurate measurements of corona loss.

INSTITUTE ACTIVITIES

Winter General Meeting for 1948 to Be Held in Pittsburgh, Pa.

Departing from the traditional practice of holding such meetings in New York City, as an innovation the AIEE 1948 winter general meeting will be held in Pittsburgh, Pa., January 26–30, in the center of the coal mining and steel industry. A broad program, covering practically the entire range of Institute technical activities, will be presented by the four main groups: industry, power, communication and science, and general applications. By virtue of location the industry group has chosen as a theme "mining and steel," with 13 sessions in prospect which center about this subject. Meeting headquarters will be in Hotel William Penn, which has excellent facilities to hold comfortably six parallel sessions per day.

Among the 13 sessions which are in prospect in the field of mining and steel are the following: interconnection (power tie with a utility) and process steam generation, power distribution in steel mills, welding in the steel industry, arc furnaces, industrial electric heating, machine tools, material handling, industrial control problems, applications to mining, and mining cables. The Association of Iron and Steel Engineers has been invited to attend and join the industry group sessions. Arrangements are in progress for trips to the Irvin Plant of the Carnegie-Illinois Steel Company and the United States Bureau of Mines in Pittsburgh. The trips will be co-ordinated with the program and a brief descriptive paper on the Irvin Works will be presented at one of the steel sessions to serve as an introduction to the trip.

In the power field, sessions on transmission and distribution, switchgear, protective relaying, extra-high voltage cables (a symposium), and generator excitation are under way. In the field of communication and basic science, arrangements are being made for several sessions, and in the field of general applications, sessions on light traction, railway electrification, and air transportation are in prospect.

The members of the general committee for the 1948 winter general meeting are

C. A. Powel, *chairman;* C. T. Sinclair, *vice-chairman;* L. N. Grier, *secretary-treasurer;* H. S. Fitch; Paul Frederick; J. R. MacGregor; A. C. Monteith.

Meeting subcommittee chairmen are

M. S. Angier, *entertainment;* R. L. Dunlap, *finance;* M. Getting, *publicity;* R. C. Gorham, *meetings and papers;* A. A. Johnson, *inspection and transportation;* B. M. Jones, *registration and information;* Mrs. G. A. Price, *ladies' entertainment;* C. M. Skooglund, *hotels.*

Cyclotron at the University of Pittsburgh in Pittsburgh, Pa., host city to the 1948 AIEE winter general meeting

Industrial Tube Survey Nearing Completion

The survey on the need for a new series of industrial electronic tubes with improved characteristics, being conducted by the joint subcommittee on electronic instruments, is about to be culminated by evaluating and totalizing the returns. Results will be published and made available to electronic tube manufacturers who are taking an active interest and co-operating with the committee.

Since this activity is expected to provide material benefit by furnishing a clear statement of the industry's need for tubes with improved characteristics, it is requested urgently that those concerns who have not returned their questionnaire, co-operate by doing so before November 15, 1947.

Power in Textile Industry. "Electric Power Applications in the Textile Industry," a pamphlet sponsored by the AIEE committee on industrial power applications, is available from the AIEE Order Department, 33 West 39th Street, New York, 18, N. Y. It contains:

'Electric Power in the Textile Industry," S. A. Bobe (*EE, Jul '47, pp 662–6*)

"Power Distribution in Textile Plants," J. D. McConnell (*EE, Jul '47, pp 667–9*)

"Electrification of the 2-for-1 Twister," E. C. Gwaltney, H. J. Burnham (*EE, May '47, pp 474–6*)

"Electric Drives for Textile Finishing Ranges," R. B. Moore, H. C. Uhl (AIEE *TRANSACTIONS, volume 66, 1947*)

Price is 80 cents (40 cents to AIEE members).

Midwest General Meeting Program

A technical program of 16 sessions and conferences and three general sessions has been arranged for the AIEE Midwest general meeting, to be held in Chicago, Ill., November 3–7, 1947. The complete program, released as this issue goes to press, appears on pages 1130–1131.

AIEE Midwest General Meeting Program, Chicago, Ill., November 3–7, 1947

Monday, November 3

9:00 a.m. Registration

10:30 a.m. Opening General Meeting

Address: "Ceiling Unlimited," **Blake D. Hull**, president, AIEE

2:00 p.m. Symposium on Tidd 500-Kv Test Lines—Part 1

47-241. Transmission of Electric Power at Extra-High Voltages. **Philip Sporn**, American Gas and Electric Service Corporation; **A. C. Monteith**, Westinghouse Electric Corporation

47-242. Corona Considerations on High-Voltage Lines and Design Features of Tidd 500-Kv Test Lines. **C. F. Wagner**, Westinghouse Electric Corporation; **Anthony Wagner**, American Bridge Company; **E. L. Peterson, I. W. Gross**, American Gas and Electric Service Corporation

47-243. Insulators and Line Hardware for Tidd 500-Kv Test Lines. **I. W. Gross**, American Gas and Electric Service Corporation; **R. L. McCoy**, Locke Insulator Corporation; **J. M. Sheadel**, Ohio Brass Company

47-244. Line Conductors—Tidd 500-Kv Test Lines. **E. L. Peterson**, American Gas and Electric Service Corporation; **D. M. Simmons**, General Cable Corporation; **L. F. Hickernell**, Anaconda Wire and Cable Company; **M. E. Noyes**, Aluminum Company of America

2:00 p.m. Industrial Power Systems

47-249-ACO.** First Interim on Interior Wiring Design for Commercial Buildings. **B. F. Thomas, Jr.**, chairman

CP.* Short-Circuit Calculations for Low-Voltage Industrial Distribution Systems. **L. E. Fisher**, Bull Dog Electric Products Company

CP.* Power Supply for Air Conditioning Equipment in Commercial Buildings. **M. N. Halberg, D. L. Beeman**, General Electric Company

Tuesday, November 4

9:00 a.m. Joint NEC-AIEE Session

(Edgewater Beach Hotel)

Note: The AIEE badge will admit registrants to this session only at the National Electronics Conference meeting

CP.* The Position Convectron, A New Type of Dynamic Vertical Sensitive Element. **M. A. Babb**, Bendix Aviation Corporation

CP.* A New Line of Thyratrons. **A. W. Coolidge, Jr.**, General Electric Company

CP.* The Glass-Enclosed Reed Relay. **W. B. Ellwood**, Bell Telephone Laboratories, Inc.

CP.* Capillary-Fed Mercury-Contact Relay. **J. T. L. Brown, C. E. Pollard**, Bell Telephone Laboratories, Inc.

9:30 a.m. Symposium on Tidd 500-Kv Test Lines—Part 2

47-245. Transformers and Lightning Arresters—Tidd 500-Kv Test Line. **F. A. Lane**, American Gas and Electric Service Corporation; **J. K. Hodnette, P. L. Bellaschi, E. Beck**, Westinghouse Electric Corporation

47-246. Switchgear Equipment for Tidd High-Voltage Test Line. **F. A. Lane**, American Gas and Electric Service Corporation; **B. W. Wyman**, General Electric Company

47-247. Instrumentation and Measurement—Tidd 500-Kv Test Lines. **R. L. Tremaine**, Westinghouse Electric Corporation; **G. D. Lippert**, American Gas and Electric Service Corporation

9:30 a.m. Care and Maintenance of Storage Batteries

CP.* The Care and Maintenance of Storage Batteries on Railroads. **R. I. Fort**, Illinois Central Railroad

CP.* The Care and Maintenance of Storage Batteries in a Steel Plant. **V. E. Schlossberg**, Inland Steel Company

1:30 p.m. Trip to Fisk Station

1:30 p.m. Trip to Western Electric Company

(Proof of citizenship is necessary)

1:30 p.m. Women's Trip to Art Institute

1:30 p.m. General Session

Address: "The Future Prospects of Atomic Energy," Doctor Enrico Fermi, department of physics, University of Chicago

2:30 p.m. Lighting Session

Address: "Invitation to attend International Lighting Exposition Conferences and Exhibits at the Hotel Stevens, November 3–7," **E. C. Huerkamp**, chairman, second International Lighting Exposition

Address: "Role of IES and ILE in Lighting Industry," **R. W. Staud**, president, Illuminating Engineering Society, and vice-chairman second International Lighting Exposition

Review of production and application of light and associated radiations:

1. CP.* Visible Radiations. **R. G. Slauer**, manager, applications laboratory, Sylvania Electric Products, Inc.

2. CP.* Infrared Radiations. **E. A. Lindsay**, General Electric Company

3. CP.* Ultraviolet Radiations. **C. F. Jensen**, Westinghouse Lamp Division

2:30 p.m. Industrial Control

47-251. A Control System for Wind-Tunnel Drives. **A. H. Heidenreich**, National Advisory Committee for Aeronautics

CP.* Modern Rotogravure Control Systems. **G. W. Heumann**, General Electric Company

CP.* Some Present-Day Practice in Mine Hoist Control. **J. W. Cook, G. W. Heumann**, General Electric Company

CP.* An Electronic Regulator for Electrolytic Processes. **W. F. Gerdes**, General Electric Company

Wednesday, November 5

9:30 a.m. Power Generation

47-250. Progress in Power Generation, 1940–46. **Power Generation Committee** (presentation by title)

47-248 Generating Reserve Capacity Determined by the Probability Method. **Giuseppe Calabrese**, Consolidated Edison Company of New York, Inc.

47-252. Calculating Probability of Generating Capacity Outages. **W. J. Lyman**, Duquesne Light Company

47-253. Outage Expectancy as a Basis for Generator Reserve. **H. P. Seelye**, The Detroit Edison Company

47-254. Probability Methods Applied to Generating Capacity Problems of a Combined Hydro and Steam System. **E. S. Loane, C. W. Watchorn**, Pennsylvania Water and Power Company

9:30 a.m. Conference on Resistance Welding

CP.* Timing Circuits in Resistance Welding Control. **B. Sussman**

CP.* Functionalized Resistance Welding Control—Safety Features. **C. B. Stadum**, Westinghouse Electric Corporation

CP.* Three-Phase Balanced Load Resistance Welding Machines. **D. Sciaky**, Sciaky Brothers, Inc.

CP.* Various Resistance Welding Systems and Their Effect on the Power Supply. **C. E. Smith**, Taylor-Winfield Corporation

12:15 p.m. Trip to Museum of Science and Industry

Women included, luncheon at the museum

1:00 p.m. Trip to South Works of the Carnegie-Illinois Steel Company

2:00 p.m. Transmission, Transformers, and Grounding

47-238. Switching High-Voltage Transmission Lines. **I. B. Johnson, J. R. Wilson**, General Electric Company

47-239. The Application of Storage Batteries to the Control of Switchgear. **E. A. Hoxie**, Electric Storage Battery Company

47-240. Gaseous Insulation for High-Voltage Apparatus. **G. Camilli, J. J. Chapman**, General Electric Company

47-255. Transient Voltage Rise in Transformers Due to Interruption of Exciting Current. **A. Srinivasan**, Allis-Chalmers Manufacturing Company; **F. J. Vogel**, Illinois Institute of Technology

47-237. Present-Day Grounding Practices on Power Systems. **AIEE Subject Committee on Present-Day Grounding Practices**

2:00 p.m. Conference on Energy Sources

The second of a series of conferences on methods of producing electric power will be sponsored by the committee on basic sciences. The first conference was held during the 1947 AIEE winter meeting in New York and three conference papers were presented, which described emission phenomena, piezoelectric phenomena, and electrostatic phenomena. At the second conference three more sources of energy will be discussed, namely, electrochemical, magnetostrictive, and thermoelectric, by outstanding experts in their respective fields. The purpose of these conferences is to present to electrical engineers a review of the fundamental principles underlying the various methods of generating electric power by authorities on these subjects. Nuclear fission will not be included in this series of conferences.

CP.* Electrochemical Phenomena. **George W. Vinal**, National Bureau of Standards

CP.* Magnetostrictive Generators. **J. A. Osborne**, Naval Research Laboratory

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*CP: Conference paper; no advance copies are available; not intended for publication in *TRANSACTIONS*.

**ACO: Advance copies only available; not intended for publication in *TRANSACTIONS*.

CP.* Thermoelectric Generators. **Grenville B. Ellis**, Squier Signal Laboratory

7:00 p.m. Visit to Marshall Field Store

Thursday, November 6

10:00 a.m. General Session

12:00 noon. Women's Luncheon and Bridge at Saddle and Cycle Club

1:00 p.m. Trip to Electromotive Division of General Motors

2:00 p.m. Trip to Armour Research Foundation

2:00 p.m. Electronic Relay Applications

This conference, sponsored by the relay committee, will be of an exploratory nature, in response to a demand occasioned by the increasing use of electronics in the electric power industry.

A thorough review of the pros and cons of the use of electronics in protective relays is planned. Such a discussion should explain the reluctance of many relay engineers to use electronic protective relays, but more important, should point the way to extended use of such devices, especially where they might provide a facility not hitherto available.

Preceding a general discussion, two conference papers will be presented. The first will deal with the more favorable aspects of electronic relays. The second will reflect the ideas of the committee's working group assigned to this subject. The paper will discuss electronic relaying more generally and will include the less favorable aspects.

CP.* Advantages of Electronic Equipment for Protective Relaying. **R. I. Ward**, Commonwealth Edison Company

CP.* The Practical Aspects of Electronic Protective Relaying. **J. H. Kinghorn**, American Gas and Electric Service Corporation

2:00 Communication

47-256. General Mobile Telephone System. **H. I. Romnes**, American Telephone and Telegraph Company; **R. R. O'Connor**, Illinois Bell Telephone Company

CP.* VHF Radio on New York Central Tugs. **G. M. Brown**, New York Central System

CP.* Standardization of Transient Response of Television Transmitters and Receivers. **R. D. Kell**, RCA Laboratories

CP.* Television R.F. Signal Generator. **Joseph Fisher**, Philco Corporation

6:00 p.m. Social Hour

7:00 p.m. Dinner-Smoker and Entertainment

Friday, November 7

9:30 a.m. Communication

47-257. The Application of Western Union Multiplex to Navy Radio. **Ray Hoover**, Western Union Telegraph Company

CP.* RCAC Time Division Multiplex. **C. W. Lattimer**, RCA Communications

47-258. Frequency Division Techniques for a Coaxial Cable Network. **R. E. Crane, J. T. Dixon, G. H. Huber**, Bell Telephone Laboratories, Inc.

CP.* The New York–Boston Radio Relay Experiment—A Progress Report

9:30 a.m. Rotating Machinery

47-259. Suddenly Applied Loads on a Variable-Ratio Frequency Changer. **G. K. Carter**, University of Virginia; **F. J. Maginniss, F. S. Rothe**, General Electric Company

47-260. Tensorial Analysis and Equivalent Circuit of a Variable-Ratio Frequency Changer. **Gabriel Kron**, General Electric Company

47-261. Resynchronizing of Generators. **C. Concordia, M. Temoshok**, General Electric Company

47-262. Two-Stage Rototrol for Low-Energy Regulating Systems. **A. W. Kimball**, Westinghouse Electric Corporation

47-263. The Circle Diagram of the Polyphase Brush Shifting Commutator Motor (Schrage Type). **P. W. Franklin**, Continental Electric Company

9:30 a.m. Basic Sciences

CP.* A Brief History of Studies in Solar Radiation. **J. T. Wilson**, Allis-Chalmers Manufacturing Company

47-264. Ignitor Characteristic and Circuit Calculations. **D. E. Marshall**, Westinghouse Electric Corporation

47-265. Determination of Corona Starting Voltages for Nonuniform Fields in Air. **J. G. Hutton**, General Electric Company

47-266. Diffusion of Electric Current into Rods, Tubes, and Flat Surfaces. **K. W. Miller**, Armour Research Foundation

—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.

—ABSTRACTS of papers listed appear on pages 1125–8 of this issue.

—PRICES and instructions for procuring advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; essential substance of many will appear in ELECTRICAL ENGINEERING.

500-Kv Tidd Test Lines

Station end of the Tidd line of The American Gas and Electric Service Corporation showing observation booth, lightning arresters, transformers, and low-voltage circuit breaker. Seven papers describing the various engineering features of the installation will be presented at the AIEE Midwest general meeting in Chicago, Ill.

Dayton Meeting Sets Record for Middle Eastern District

The Middle Eastern District meeting held in Dayton, Ohio, September 23–25, 1947, with headquarters at the Dayton-Biltmore Hotel, is the first such meeting that the District has held since October 1940 when the District met in Cincinnati. A meeting originally planned for October 1942 in Pittsburgh, Pa., was canceled because of war conditions. The District meeting program in the Middle Eastern District was instituted in 1925 when a meeting was held in Washington, D. C. Subsequently, the Cleveland, Bethlehem, Philadelphia, Pittsburgh, Akron, and Scranton Sections each have sponsored one District meeting, and Baltimore and Cincinnati have sponsored two each. The 1949 Middle Eastern District meeting is scheduled to be held in Washington, D. C., under the sponsorship of the Washington Section in October 1949.

The Dayton Section, organized in June 1943, is one of the youngest Institute Sections to have undertaken the responsibility of a major meeting. The success of its efforts and its program are attested to by the verified attendance of 502 persons, a total which establishes a record for the District second only to the attendance figure of 599 for the Cincinnati meeting in 1940.

L. F. Fritz, first chairman of the Dayton Section and general chairman of the current Middle Eastern District meeting committee, presided at the opening general session, at which Mayor Edward Breen of Dayton gave an informal address of gracious personal welcome to which G. W. Bower AIEE, vice-president for the Middle Eastern District, responded.

TECHNICAL SESSIONS

In addition to the opening general session, a total of eight technical sessions made up the meeting program, one devoted to industrial electronics, three devoted to air transportation topics, and four devoted to rotating machinery topics, principally concerning small motors. These sessions accommodated the presentation and discussion of 28 technical papers and 12 conference papers, and several informal contributions. Although all sessions drew relatively heavy attendance, ranging from about 90 to about 150, the heavily technical sessions on electric motors drew by far the heavier attendance and inspired the most active discussion.

A résumé of the technical highlights brought out in these sessions is given elsewhere in these pages. Many of the topics, including some of the conference papers, are scheduled for a more thorough treatment in early issues of *ELECTRICAL ENGINEERING.*

INSPECTION TRIPS

To avoid conflict in interest between inspection trips and technical sessions, the entire afternoon of the middle day of the 3-day meeting was given over to inspection trips. Four organized trips were offered: one to the McCall Corporation, where the operations involved in the manufacture of dress patterns, and also the operations involved in the large-scale production of periodical publications, were available for inspection; to the Delco Products Division of the General Motors Corporation, where the various manufacturing processes involved in the production of electric motors and various automotive accessories were observed; to the National Cash Register Company's plant, one of the pioneers in the manufacture of cash registers and various business machines; to the Dayton Rubber and Manufacturing Company's plant, where the various steps involved in the manufacture of such rubber products as tires, tubes, belts, and other industrial items were demonstrated.

On Thursday, the third day of the meeting, two separate inspection groups, one in the morning and one in the afternoon, were taken for an extensive tour of the United States Air Forces' huge Wright Field Headquarters establishment of the Air Matériel Command where a special program of demonstrations and exhibit was presented for the edification of the visitors. Participation in the Wright Field inspection trips was limited to those able to produce satisfactory evidence of citizenship (United States or Canada) at the time of registration for the trip. The overwhelming popularity of the Wednesday inspection trip to the Delco Products Division of General Motors necessitated the organization of a second trip to this plant Thursday afternoon. All of the plants visited arranged generous special programs for the visitors.

SOCIAL ACTIVITIES

Principal general affair of the social program was an informal banquet held Wednesday evening, September 24, in the ballroom of the Dayton-Biltmore Hotel, which was presided over by Milton H. Wagner (F '30) local civic leader and vice-president of the Kelso-Wagner Company, Inc. Among the special guests introduced by Chairman Wagner were AIEE President Blake D. Hull; Doctor Arthur E. Morgan, former president of Antioch College at Yellow Springs, Ohio, and former head of the Tennessee Valley Authority; and Doctor Henry T. Gillett, former mayor of Oxford, England, who was visiting Doctor Morgan incidental to a visit to the United States under the auspices of the Friends World Conference. Each of these spoke briefly, President Hull outlining the salient features of AIEE plans and objectives, Doctor Gillett giving something of a personal insight into the currently serious economic and political situation involving Great Britain and stating as his opinion that in the long run England would tend to develop "toward the right rather than toward the left," Doctor Morgan reviewing some of the experiences of his recent visit to Finland as a technical consultant in connection with the Finnish Government's project of maximum development of hydroelectric power resources to reduce that nation's requirements for imported fuels. The principal speaker of the evening was the Reverend Fay LeMeadows who delivered a humorous address on the subject "Life Can Be Fun."

The feature of the men's entertainment program was a stag smoker held in the commodious building of the Engineer's Club of Dayton, and including a stage show and buffett supper.

Special features arranged particularly for the women guests included a luncheon, fashion show, and bridge party held Tuesday afternoon in the dining room of the Rike-Kumler Department Store, and a special sight-seeing tour to numerous points of local interest Wednesday afternoon. Also, 20 out-of-town women guests attended a local showing of the motion picture "Life With Father" as the guests of the local committee.

EXECUTIVE MEETINGS

An all-day meeting of the Middle Eastern District executive committee was held Monday, September 22, preceding the District meeting program. This meeting is reported in some detail elsewhere in the news pages of this issue (pp *1133–4*).

The AIEE publication committee, under the chairmanship of B. M. Jones of Pittsburgh, held a meeting in the Engineer's Club of Dayton, Thursday, September 25, to consider publication plans and budget requirements for the 1947–48 administrative year. On the basis of membership responses that have been received to date, the committee plans to continue without major change, but with further development and improvement, the present-day AIEE publication policy as it was explained in the December 1946 issue of *ELECTRICAL ENGINEERING* and inaugurated with the January 1947 issue.

The AIEE air transportation committee also met incidental to the Middle Eastern District meeting, at the Engineer's Club of Dayton, Friday, September 26, for an extended session to develop specific plans and operating procedures for the committee's functioning under the new AIEE technical committee setup as outlined in a recent issue of *ELECTRICAL ENGINEERING* (*EE, Oct '47, pp 1006–11*).

An informal luncheon conference of the Middle Eastern District's Student Branch counselors was held at the Dayton-Biltmore Hotel, Wednesday, September 24, under the chairmanship of Professor P. L. Hoover of the Case School of Applied Science, Cleveland, chairman of the Middle Eastern committee on Student activities. Present also were President Hull, Secretary Henline, Vice-President Bower, District Secretary Muir, and Editor Henninger. Out of the random discussion of this informal conference, a tentative agenda was initiated and preliminary plans made for the holding

of a formal business conference of Student Branch counselors and Student Branch chairmen in Cleveland in mid-November, probably the 14th and 15th.

DISTRICT MEETING COMMITTEES

Since the Dayton Section first was organized in June 1943, having grown in four short years from a status of a Cincinnati Subsection to a strong and active young Section in its own right, one of the major objectives toward which the Section has been aiming has been the sponsorship of a Middle Eastern District meeting. These plans were brought to a very successful conclusion, in the meeting recently held in Dayton, under the direct efforts of the following committee personnel:

General Committee

M. H. Wagner, Sr., *honorary chairman*
L. J. Fritz, *general chairman*
G. B. Hamm, *secretary-treasurer*
W. R. Appleman
W. A. Barden
C. T. Button
W. A. Dynes
J. W. Gehrke
F. S. Himebrook
J. M. Rodgers
G. I. F. Theriault

Scheduling Committee

J. M. Rodgers, *chairman;* W. R. Appleman; W. A. Barden; C. T. Button; W. A. Dynes; L. J. Fritz; J. W. Gehrke; G. B. Hamm

Technical Papers Committee

W. R. Appleman, *general vice-chairman;* C. T. Button; J. L. Fuller; J. H. Karr; T. J. Martin; E. C. Merkle; J. M. Rodgers; C. H. Spitler; H. S. Starbuck; J. L. Trant; C. G. Veinott; Alan Watton; R. F. Zimmerman

Entertainment and Publicity Committee

C. T. Button, *general vice-chairman*

Entertainment Committee

G. I. F. Theriault, *chairman*

Ladies' Entertainment Committee

Mrs. G. I. F. Theriault, *chairman;* Mrs. W. A. Dynes; Mrs. L. J. Fritz; Mrs. F. S. Himebrook

Publicity Committee

E. J. Bates, *chairman;* R. E. Mumma; R. S. Hull

Photography and Printing Committee

J. O. Lang, *chairman;* C. Higgins

Inspection Trips and Transportation Committee

R. W. Hommel, *chairman*

Meeting Highlights and Student Activities Committee

F. S. Himebrook, *chairman;* E. C. Merkle; G. B. Hamm; M. H. Wagner, Jr.

Registration and Finance Committee

J. W. Gehrke, *general vice-chairman*

Hotels and Registration Committee

W. M. Gallagher, *chairman;* W. J. McLain; T. E. Noren

Finance Committee

H. E. Deardorff, *chairman;* E. J. Bates; L. J. Fritz; H. M. Joy; W. F. Ridge; J. E. Smith; R. E. Stowe; G. I. F. Theriault; C. Werner

Analysis of Registration at Dayton, Ohio

Classification	Dayton Section	District 2*	Other Districts	Totals
Members	118	144	77	339
Students	13	16	5	34
Men guests	39	35	23	97
Women guests	18	11	3	32
Totals	188	206	108	502

* Outside Dayton.

Middle Eastern District Meeting Attendance 1925–1947

Date	Location	Attendance
1947—Sept. 23–25	Dayton, Ohio	502
1940—Oct. 9–11	Cincinnati, Ohio	599
1939—Oct. 11–13	Scranton, Pa.	313
1937—Oct. 13–15	Akron, Ohio	464
1932—Oct. 10–13	Baltimore, Md.	240
1931—Mar. 11–13	Pittsburgh, Pa.	500
1930—Oct. 13–15	Philadelphia, Pa.	500
1929—Mar. 20–23	Cincinnati, Ohio	270
1928—Apr. 17–20	Baltimore, Md.	400
1927—Apr. 21–23	Bethlehem, Pa.	400
1926—Mar. 18–19	Cleveland, Ohio	430
1925—Jan. 23–24	Washington, D. C.	212

District 2 Executive Committee Holds Meeting in Dayton, Ohio

The Middle Eastern District executive committee, under the chairmanship of AIEE Vice-President G. W. Bauer, held an all-day meeting at the Biltmore Hotel in Dayton, Ohio, Monday, September 22, 1947, preceding the Middle Eastern District meeting which began there the following day. Some 43 Section chairmen, vice-chairmen, secretaries, or delegates were present representing the District's 15 Sections. Also present were District Secretary A. C. Muir, District Vice-Chairman F. H. Knapp of the AIEE membership committee, Chairman P. L. Hoover of the District committee on Student activities, Chairman L. J. Fritz of the Middle Eastern general committee, W. A. Dynes (of Dayton) of the AIEE Section committee, and AIEE Secretary H. H. Henline.

In reference to future meetings in the District, the committee voted to recommend a District meeting in Washington, D. C., October 19–22, 1948. It also voted to recommend consolidation of the 1949 District meeting with the Midwest general meeting for that year, which was recommended for Cincinnati during the week of October 17–21, 1949. The Cleveland Section submitted a tentative request for the 1950 District meeting to be held in Cleveland in the fall of 1950, but indicated also that informal consideration was being given to the idea of requesting the 1952 AIEE summer general meeting instead. In discussing membership activities, all Sections reported active growth and active membership committees. Extended discussion gave emphasis to three points regarded as of cardinal importance as a sound foundation for AIEE membership growth:

1. Active Section programs which provide generous opportunity for active individual participation in Section affairs.

2. The size and makeup of local membership committees should be such that the committees will be widely representative of the various industries in the areas, and the committee must be active.

3. The interest and professional qualifications of membership applicants should be evaluated carefully to assure the maintenance of a high level of professional quality in AIEE membership, and to assure also that there is an active and constructive interest in AIEE activities.

Discussion of the question of local memberships versus national memberships revealed the consensus that in certain instances local memberships may be mutually beneficial in the smaller Sections and Subsections, but that care should be exercised to avoid bringing in as local members persons having the professional qualifications for national membership and full participation in the AIEE activities.

STUDENT BRANCHES

Co-operation in Student Branch activities is being given by most Sections, the more active Sections taking an active part in collaboration with Student Branches within their areas. Some of the Sections arrange annual joint Section–Branch meetings, sometimes sponsored by the Section and sometimes sponsored by the Branch. Others make particular effort to provide opportunity for Student Branch chairmen and other Branch representatives to take an active part in Section affairs. Still others follow the practice of having Section officers or other Section representatives present at each meeting of the Student Branch within the Section territory. The community of interest, opportunity, and responsibility actually existing between AIEE Sections and the Student Branches within their Section territories, represents one of Vice-President Bauers' theme songs, and his efforts are bringing results.

PRIZE PAPER COMPETITION

The subject of District prize paper competition excited considerable discussion. Vice-President Bauer pointed out that one, and possibly two, prize awards committees will be needed for judging District, Section, and Student Branch papers. He requested the District executive committee to transfer authority for the appointment of these two committees to the District co-ordinating committee, and the executive committee took formal action accordingly. Mr. Bauer reported also that under the new AIEE rules governing AIEE paper prize awards which become effective January 1, 1948, no provision is made for AIEE initial paper prize, nor is any provision made for District or Section prize paper awards except for Student papers. The new rules do provide for a branch paper prize of a maximum of $10, and travel allowance of seven cents per mile for the winner of each Student Branch prize paper contest to attend a District contest meeting. They also provide for a District Student paper prize award of $25 in cash. Mr. Bauer stated that the Middle Eastern District intends to take full advantage of both the old rules and the new

rules, by arranging a prize award for the best paper and the initial paper presented in the Sections of the District during the calendar year of 1947, and by arranging also a series of Branch prize paper contests and a District Student prize contest for that part of the administrative year beginning January 1, 1948.

As members of the District co-ordinating committee, the executive committee elected W. A. Barden of the Dayton Section, R. F. Norwood of the West Virginia Section, M. W. Kitzmuller of the Erie Section, and F. J. Ilse of the Akron Section. Preliminary arrangements were made for visits of the vice-president to the various Sections and Branches during the year.

F. S. Black of the Washington Section was elected as the District 2 representative on the AIEE nominating committee, the executive committee by formal action leaving its delegate "uninstructed in regard to the presidential nomination."

SUBSECTIONS

Discussion of the general topic of Subsections elicited the consensus that, in general, Subsections, if thoughtfully organized, "give Institute activities a wider field and gain the interest of many more persons," although it was agreed that not all Sections can use the Subsection plan to constructive advantage. Mr. Bauer described the three types of Subsections as

1. A Subsection which is formed with the intention of reaching Section status.

2. A Subsection which always will be too small to be a Section.

3. A Subsection which operates close to the parent Section and prefers to remain a part of a relatively large Section rather than to break away and become a separate Section.

Each of these has its place, and decisions involve evaluation of local factors and the use of sound judgment.

Vice-President Bauer briefly reviewed the highlights of various types of Section activities, and urged each individual Section to use as many of these activities as possible to expand its local activities to retain the diversified interests of the older members, and to gain the interests of younger members and prospects. Such activities include educational courses, local councils of engineering and technical societies, safety activities, transfer activities, fellowship, social activities, inspection trips, Section finance and administration, Section publicity, Section history, and the use of identification cards or badges at meetings. He urged each Section to make a practice of sending items of Section and District news importance to *ELECTRICAL ENGINEERING* for publication.

MESSAGE OF CONDOLENCE

As an expression of sympathy on the recent death of W. E. Wickenden, AIEE past president and member of the Cleveland Section, a resolution was passed that the following letter be written to Mrs. Wickenden:

The District executive committee of the AIEE Middle Eastern District 2, which includes the Cleveland area, at its meeting held in Dayton, Ohio, Monday, September 22, 1947, unanimously passed a resolution offering to you our deepest sympathy in your recent bereavement. District 2 and the Institute have lost a far-sighted capable leader and a very true friend of all AIEE members.

Four Rotating Machinery Sessions Held at Dayton Meeting

Various aspects of rotating machinery were the center of much attention at the Middle Eastern District meeting. So much so, that four separate sessions were held on this subject; two on Tuesday, one on Wednesday, and one on Thursday. The sessions were well attended and a lively discussion followed most of the papers. Two sessions were devoted to leakage reactance, one to motor design, and one to the processing and testing of motors.

Leakage Reactance

Leakage reactance was discussed at two separate sessions, Tuesday morning and afternoon. W. R. Hough (M '41), presided over the morning session.

Equivalent electric circuits were introduced to facilitate performance calculations of a-c apparatus at an early period in the history of these machines. After more than 40 years the accurate calculation of some of the circuit constants such as the leakage reactances remain as one of the most difficult and uncertain parts of the design procedure. The papers and discussions of both sessions were directed toward clarification of the physical concepts of reactance, definition of the basic assumptions and theoretical errors in established procedures of calculating reactance, and explanation of some newer methods of computing the air-gap components of the leakage reactance.

PHYSICAL CONCEPTS

Professor J. H. Kuhlman (M '27) University of Minnesota, Minneapolis, Minn., presented his paper on the "Physical Concept of Leakage Reactance" and set the stage for the papers and discussions which followed. This paper was a nonmathematical discussion of the general concept of leakage reactance as it exists in the transformer, the induction motor, the synchronous machine, and the d-c machine. He pointed out that in every magnetic circuit linking more than one winding, there is always some flux that follows local paths and does not link both windings; this is called the leakage flux. The leakage flux paths are in air or in magnetic circuits of low saturation so that the flux is directly proportional to the current. If the permeability of the leakage flux path is constant the leakage reactance also will be constant. The leakage reactance multiplied by the current is called the leakage drop in the winding and it leads the current in time phase by 90 degrees.

SLOT CONSTANTS

The basic assumptions involved in conventional methods of calculating slot leakages were given in a paper by A. F. Puchstein (M '27) of the Jeffrey Manufacturing Company, entitled "Calculation of Slot Constants." Formulas were cited for many slot shapes. The discussions on slot leakage were directed at two of the assumptions in the conventional method. A field map of the slot was suggested as a possible improvement on the conventional assumption of parallel lines of leakage flux across the slot. The difficulty of expressing the results of the flux plot in a form which could be handled readily by integral calculus was pointed out.

The errors introduced by the assumption of zero reluctance for the iron part of the leakage flux path were shown to be of significant magnitude when parts of the leakage path were saturated. The exact determination of saturation of each volume of iron in the leakage path was shown to be a difficult problem. Reference was made to technical literature which presents practical methods of modifying the slot leakage to take account of magnetic saturation.

EXPERIMENTAL STUDY PROGRAM

A report on an experimental study now in progress for the isolation and determination of the end-turn leakage reactance of small integral-horsepower polyphase induction motors was presented by E. C. Barnes (A '41) Reliance Electric and Engineering Company, Cleveland, Ohio. To determine experimentally the end-turn leakage of a particular type of winding, he plans to build motors with several stack lengths but with all other factors as nearly constant as possible. A curve of stalled reactance will be plotted as a function of stack lengths and extrapolated to zero stack to obtain the end-turn leakage of the particular winding. By repeating these procedures for several motor diameters, numbers of poles, and coil pitches, it is hoped that valuable data on the variations of the end-turn leakage with each of these variables will be obtained.

AIR GAP REACTANCE

The calculation of air gap reactance was approached by two separate procedures. One of these was presented in a paper called "The Air Gap Reactance of Polyphase Machines," by P. L. Alger (M '30) General Electric Company, Schenectady, N. Y., and H. R. West (M '28) of the same company in Pittsfield, Mass. This method was based on the lumping of all harmonic fluxes and considering their combined effect on reactance as functions of slots per pole, number of phases and skew. The formulas derived in the paper enabled the differential leakage or zigzag reactance of any

motor or induction regulator to be calculated with good accuracy, whatever the width of slot openings and whatever the ratio of primary to secondary slots.

EQUIVALENT CIRCUIT METHOD

The other method of air-gap reactance calculation was presented in a paper called "Leakage Reactance of the Squirrel Cage Rotor with Respect to the Stator Harmonics and the Equivalent Circuit of the Induction Motor" by M. M. Liwschitz (M '39) of the Polytechnic Institute of Brooklyn, Brooklyn, N. Y. He presented a method based on separate analysis of the effects of each space harmonic and summed these effects in an equivalent circuit formed by placing the conventional equivalent circuit for the fundamentals in series with similar circuits for each harmonic.

CALCULATION DIFFICULTIES

Some difficulties in the calculation of leakage reactance were discussed by W. H. Formhlas (M '44) of the Westinghouse Electric Corporation, Buffalo, N. Y., and M. M. Liwschitz (M '39) of the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., in a paper called "Some Phases of Calculation of Leakage Reactance of Induction Motors." The influence of slot openings, skewing, saturation of leakage paths, and aluminum film on the rotor on the differential leakage was discussed. In each case it was shown that use of the usual assumptions made in calculating the differential leakage resulted in inaccuracies. These inaccuracies, the authors claimed, make theoretical methods of calculation tedious and lead the designer to use more practical methods of calculation, corrected by constants gained from tests. It was pointed out that the present knowledge of the theory of electric machines does not yield an exact method of calculation of the differential leakage and of the magnitude of the effect of saturation on the leakage reactances. Manufacturing methods introduced further uncertainties in the magnitude and the influence of skew and of aluminum film on the leakage reactances. These circumstances cause a designer to depend upon correction factors which are based on tests on his particular machines. Thus, not theory alone, but theory in connection with experience enables a designer to adapt the electric machine to all possible kinds of applications and to meet the guarantees fixed by the standards of the customer.

PERMEANCE METHOD

Another method of calculating total leakage reactance was described in a paper called "Reactances of Induction Motors," by T. C. Lloyd (M '46), V. F. Guisti (A '44), and S. S. L. Chang (Student Member) all of Robbins and Myers, Inc., Springfield, Ohio. This method was based on three premises, that the fundamental calculation should be the same for either single-phase or polyphase motors, modifying only the later steps in the process for the two types; that the calculations should be based on permeances of the magnetic paths for ease in handling many calculations in the same laminations; and that only the slot, zigzag, and end connection permeances be used in determining leakage reactance.

TEST RESULTS

Test results of a 4-pole 2-horsepower 3-phase induction motor were presented in a paper called "Test Results of Motor Used for Leakage Reactance Calculations," by A. L. Poliquin (A '43) of the Master Electric Company, Dayton, Ohio, and A. S. Bickham (M '46) of Whirl-A-Way Motors, Inc., Tipp City, Ohio. The conditions of the test and test results were presented by A. L. Poliquin. The test results were compared with predicted results calculated by representatives of several manufacturers. All calculated quantities were within eight per cent of the test results. A request was made for a report on these calculations and P. L. Alger (M '30) was appointed chairman of a committee to collect calculations and edit the report.

INFORMAL DISCUSSION

An informal discussion of leakage reactance on a sample motor was led by E. C. Barnes, B. M. Cain (General Electric Company), W. H. Formhals, and T. C. Lloyd.

Motor Design

Wednesday's session, presided over by C. G. Veinott (M '34), was devoted to the motor design aspect of rotating machinery. The session was well attended, about 275 people present, and it was notable for much informal discussion which indicated a considerable interest in the seven papers that were presented.

HYSTERESIS MOTOR

The paper "The Hysteresis Motor—Advances Which Permit Economical Fractional-Horsepower Ratings," presented by H. C. Roters (M '42) of the Fairchild Camera and Instrument Corporation, Jamaica, N. Y., covered a subject on which very little has been published. The changes in the art which have made practical synchronous hysteresis motors of relatively large power outputs and high efficiencies, were described. Some of the motors described were as large as one-seventh horsepower with an efficiency as high as 73 per cent. The advances responsible for this improvement are the development of a method eliminating spurious hysteresis loss in the rotor of the motor and the development of a method of reducing the exciting current. The former is achieved by using a winding distributed in a finite number of slots, the openings of which are closed. This reduces the spurious hysteresis rotor loss by approximating an ideal revolving field. The latter development, reducing the exciting current, is achieved in certain applications when it is feasible to over-excite momentarily the rotor. It is then possible to produce a state of permanent magnetization in the rotor such that the required exciting current is reduced greatly. The use of improved magnetic materials also has contributed to making the hysteresis synchronous motor comparable in size and efficiency with the ordinary induction motor.

A written discussion by B. E. Lenehan (A '24) Westinghouse Electric Corporation, Newark, N. J., was read by T. E. Carville (M '32) of the same company, because Mr. Lenehan was not present. The effects of heat treating and annealing were discussed by M. C. Falk (A '40) of the Jones and Laughlin Steel Corporation, Pittsburgh, Pa. A general discussion followed which included questions presented by P. L. Alger.

SHADED POLE MOTORS

Another little-treated subject was discussed by P. H. Trickey (F '47) of Diehl

Absorbed in conversation at the recent AIEE Middle Eastern District meeting in Dayton, Ohio, are (left to right) W. R. Appleman (M '35) vice-chairman, technical sessions; G. W. Bower (M '40) vice-president, District 2 (Middle Eastern); and A. C. Muir (M '39) secretary, District 2

Manufacturing Company, Somerville, N. J., who presented a paper called "Performance Calculations on Shaded Pole Motors." Except for his previous paper (*EE, Sept '36, pp 1007–14*), little is in print on this subject. The present paper extended the work of the earlier paper, deriving equations for performance under running conditions, and presented a calculation sheet or form for performing readily the mathematical operations. It was an excellent presentation and was well received. The subject is very complex but the author presented the paper in the hope of spurring future work.

There was an informal discussion on the paper by A. F. Puchstein (M '27); E. E. Kimberly (M '41) of Ohio State University, Columbus, Ohio; H. Stone (A '46), Robbins and Myers, Inc., Springfield, Ohio; and Doctor K. Y. Tang (M '32) of Ohio State University, Columbus, Ohio.

D-C MOTORS

A method of calculating the magnetization curve, electrical winding, and operating performance of a fractional-horsepower industrial d-c motor, was given in a paper called "Design of Fractional Horsepower Direct Current Motors" by O. M. Swain (M '45) Westinghouse Electric Corporation, Lima, Ohio. Empirical means of determining approximate motor size and proportions, based on a line of motors covering the complete fractional horsepower range was included. Careful handling of the magnetic circuit results in an accurate method of d-c motor design with some advance in degree of accuracy over that usually expected. The magnetization curve is built up step by step from curves of the component parts of the magnet circuit. Starting with an estimate of motor efficiency, a straightforward procedure was given for determining the number of turns and the size of wire for the windings, and the performance under various conditions of loading.

A. F. Puchstein (M '27) of the Jeffrey Manufacturing Company, Columbus, Ohio; L. A. Doggett (F '36) of Pennsylvania State College, Pa.; J. H. Karr (M '46) of Robbins and Myers, Inc., Springfield, Ohio; and C. H. Spitler (M '45) of the Leland Electric Company, Dayton, Ohio, participated in an informal discussion on the paper.

CAPACITOR START MOTORS

A new method of analysis of capacitor-start motors which involves the use of curves, was the subject of the paper "A Design Method for Capacitor-Start Motors" presented by S. S. L. Chang (Student Member) of Robbins and Myers, Inc., Springfield, Ohio. The method was unique in that it reduced the number of parameters by the use of ratios which led to the use of comparatively few curves from which design elements can be read directly. The author pointed out that the curves saved time once they are prepared, and they also offer the additional advantage of enabling the designer to observe trends in his choice of values. Operation near maximum points, and the possible influence of changing certain parameters readily are observed when such curves are used.

Limits on design were discussed and verified approximately by some work of L. C. Schaeffer (A '39) Westinghouse Electric Corporation, Lima, Ohio. The paper also was discussed informally by M. L. Schmidt (M '43) of the General Electric Company, Ft. Wayne, Ind.

A-C BRUSH-SHIFTING MOTOR

The final paper at Wednesday's session, "Impedance Relationships of the Adjustable-Speed A-C Brush-Shifting Motor" by F. Baumann, General Electric Company, Schenectady, N. Y., was presented briefly by L. M. Nowacki (M '45) of the same company, in Mr. Baumann's absence. The object of the paper was to present a new and simple method of calculating the performance of an adjustable speed a-c brush-shifting motor by the equivalent-circuit method. It was pointed out that the usual assumption of neglecting the reactance which is mutual to the primary and commutated winding may lead to considerable error. The analysis showed the part which each of the mutual and leakage reactances play in determining the performance of the machine. The paper had to be treated briefly because the time for the session ran out.

Processing and Testing

Thursday's rotating machinery session, comprising five papers, confined itself to the processing and testing of rotating machinery. The session was presided over by W. R. Appleman (M '35) of the Master Electric Company, Dayton, Ohio.

COPPERSPUN ROTOR

The method of fabrication of a 1-piece squirrel-cage rotor cast of copper by a centrifugal process, was the subject of the paper "The Copperspun Squirrel-Cage Rotor" by G. R. Anderson (M '29) of Fairbanks, Morse and Company, Beloit, Wis. The essential substance of this paper has appeared in *ELECTRICAL ENGINEERING* (*EE, Oct '47, pp 980–2*).

PRECISION DYNAMOMETER

An interesting instrument was described in a paper called "A High Precision Dynamometer for Small Motor Measurements," by J. E. Duff (M '47) of the Hoover Company, North Canton, Ohio. The dynamometer discussed was one which had been designed primarily to minimize errors caused by mechanical weaknesses rather than electrical ones and has been restricted in its design to a unit which is satisfactory only for motors having speeds less than 7,200 revolutions per minute, and power outputs of less than 50 watts. The combination of the induction generator type of dynamometer together with a variable frequency power source and oppositely rotated trunnion bearings produced a very satisfactory dynamometer for small shaded-pole induction motor test work. It was pointed out that with the exception of the precision machine tool work required for certain parts, its construction was not excessively difficult. The performance of the instrument is excellent. When used as a generator to absorb power, its sensitivity is well below one per cent of total torque. Normally the loading is that of the induction generator type, however for tests of starting torque it is necessary to excite the fields with direct current and to use the unit as an absorption dynamometer. Heating is not excessive under these conditions if tests do not take too long. The dynamometer is not designed for continuous use as an absorption unit.

TEMPERATURE RECORDER

Another interesting instrument described was a self-balancing potentiometer recorder. This unit was discussed in the paper "Expediting and Improving Heat Runs with a Multipoint Temperature Recorder," by J. L. Fuller (M '45) of the Reliance Electric and Engineering Company, Cleveland, Ohio. This unit is a 16-point self-balancing potentiometer recorder for thermocouple temperatures. It was designed to avoid difficulties and inconsistencies which always have been encountered in making heat runs on induction motors by the conventional thermometer method. The author pointed out that using the recorder for heat runs has proved very successful. Contributing factors to the success of the method were: the use of thermocouples instead of thermometers which permitted accurate placement and practical covering of the temperature sensitive element; elimination of the human element in recording temperatures which is particularly important at the time of shut-down; and removal of the requirement for recording temperatures which permitted the tester to do a more accurate job of controlling test conditions. It also was found that the time requirement for heat runs for development work could be reduced materially. The time reduction was accomplished by initial overloading and determining accurately the time to restore full load by comparing the active temperature curve on the chart with previous runs on similar motors. Continuous runs in two to three hours by this method are not uncommon. By watching temperature changes after restoring full load it can be determined if more overloading is required or whether the load should be reduced for a time.

SURGE TESTING

A surge comparison testing procedure that can be adapted readily to testing fractional horsepower motors quickly and in large quantities, was described in a paper called "The Application of Surge Comparison Testing Equipment to Fractional-Horsepower A-C Stator Windings," by L. W. Buchanan (A '38) of the Westinghouse Electric Corporation, Lima, Ohio. The surge comparison test is a means of applying voltage to two motor windings and comparing them to determine if there are any discrepancies or breakdowns in insulation. A surge of steep wave front is applied to the two windings connected in

series and the voltage wave across one of them is recorded on an oscilloscope. On each successive surge the two windings are interchanged. If the two windings are identical, the trace on the oscilloscope will be the same for each surge, and if the windings are different, the traces will not coincide. Because the oscilloscope screen retains the trace for a short period, two images will appear. The surges, of very short duration, only a few microseconds long, are applied 60 times each second. The energy supplied to the test windings is very low, consequently the voltage can be increased sufficiently to give a test of insulation without damaging the windings due to heating.

HERMETIC MOTORS

A paper describing the application of motors to hermetic compressors was called "The Design and Application of Hermetic Motors" by F. L. Slade, Century Electric Company, St. Louis, Mo. The author pointed out the extent to which such motors differ from conventional motors in performance, mechanical design, and materials used. For purposes of his discussion the author considered a hermetic motor, one sealed in a housing with a refrigeration compressor and subjected to dichlorodifluoromethane and oil. The application is not new, but improvements in materials and manufacturing methods in the past few years have increased interest in this type of motor. The motor consists of a wound stator with a shaftless rotor mounted vertically or horizontally in the compressor housing. The compressor manufacturer provides cooling by one of several means to prevent temperatures in excess of accepted limits for class *A* insulation. Some of these are: drawing the refrigerating gas over the motor windings and through the rotor or over the stator shell; or providing suitable passages around the periphery of the stator through which the oil is circulated for cooling; or in smaller sizes, usually less than one horsepower, the motor can be cooled satisfactorily by direct radiation with a finned housing to aid in heat transfer. The motor rotor is pressed on an extension of the compressor crank shaft. Lubrication of the unit by splash or pressure system may cause oil to impinge on the stator windings which are protected against erosion by baffles or winding protectors of fiber or other suitable material. Leads from the stator are carried through the housing by insulated bushings which may use a plastic for insulation, or a simpler means is the use of steel wire fused in glass, the steel being an alloy having a coefficient of expansion comparable to that of glass. Single-phase motors may be either capacitor start, induction run, or capacitor start and run. Because the basic electrical design is comparable to a conventional motor, the manufacture of hermetic motors is primarily a problem of selection of the special materials and accessories required, and control of manufacturing operation to prevent introduction of injurious foreign material.

Air Traffic Control Session Stresses Operational Safety

An air traffic control equipment session was held Thursday morning during the Middle Eastern District meeting. Four technical papers and one conference paper were presented at the session which was presided over by J. D. Miner, Jr. (M '42). The papers covered various aspects of traffic control from the use of air-borne radar to airport runway and approach lighting, and stressed safety of aircraft operation, especially during adverse weather conditions.

TRAFFIC CONTROL

The first paper described the little-known service of air traffic control, and served as an introduction to the subject of the session. It was a conference paper called "Air Traffic Control," and was presented by C. W. Carmody of the Civil Aeronautics Authority. The service of air traffic control is performed by air route traffic control centers that have jurisdiction over air traffic enroute between terminals; and by airport traffic control towers that handle the traffic on and in the vicinity of the terminal. Both are operated by the Civil Aeronautics Authority, and have a primary responsibility for the prevention of collision between aircraft under adverse weather conditions. Within such limits, the air traffic control service provides for the most efficient use of air space, facilities, and airports. The major reason for delays and uncompleted scheduled flights is the inadequacy of facilities, most of which were developed and installed in the late 1920's, to to handle 1947 traffic. The war interrupted the replacement of these obsolete facilities and now an extensive program of new facilities is well under way. The program includes installation of very-high-frequency instrument landing systems at more than 100 airports, over 400 omnidirectional very-high-frequency radio ranges to which distance measuring equipment will be added later, and an extensive very-high-frequency 2-way air-ground communication system. Co-ordinated with the development of these facilities is the development of an air-borne offset course computer, which presents almost limitless possibilities in the setting up of multiple airways and air routes. Somewhat further in the future is the development of automatic communications and posting equipment for the handling of flight data. Considerable development work is being carried on regarding the adaptation of radar to civil use, and a number of serious technical problems remain to be solved.

AIR-BORNE RADAR

A 50 per cent decrease in air transportation accidents is to be expected if air-borne radar is installed and operated properly. This was the conclusion reached in a paper called "Using Air-borne Radar to Increase Air-line Safety," by R. W. Ayer, American Airlines, Inc., La Guardia Field, N. Y. It was pointed out that minor but significant modifications to existing *X*-band air-borne radar types have made it practical for the pilot himself to use radar for avoiding collisions with terrain. The equipment can be used for emergency negotiation of let-downs over terrain surrounded by hills, for avoidance of dangerous areas of precipitation and their associated turbulence whether flying over land or water, and as a supplementary navigational aid where water-land or other contrast exists in the radar echoes. Using the same modified *X*-band air-borne radar against ground responders, a simplified navigation system has been developed which improves the precision of flying in areas of high traffic density, and provides a means of making multidirectional low approaches to an airport under conditions of low visibility. The continuous information on ground speed provided by air-borne radar provides substantial economies in long hauls by permitting quick selection of the most favorable flight level. A procurement program for a suitable pilot-operated transport radar has been undertaken co-operatively by the Army, Navy, and an air line after one year of flight development and service test work by the air line. It also was mentioned that because air-borne radar indicates immediately when it fails to operate or when it operates improperly, it is considered inherently a self-checking device. This feature greatly enhances its value. A survey of accidents in scheduled air-line operation over a period of five years indicates a preponderance of accidents in which the aircraft apparently flew into a hill, usually at night, and apparently without the pilot's being forewarned. Some 500 hours of flight and service test experience using air-borne radar indicates that if the past accident pattern continues to prevail, air-borne radar is capable of reducing 50 per cent of these accidents.

LANDING AIDS

The problem of landing aircraft under adverse weather conditions generally has been recognized as the most troublesome and dangerous of adverse-weather flying problems. How the problem is being investigated at a test station was described in a paper called "Landing Through Overcast," by W. T. Harding (A '44) of the Air Matériel Command at Wright Field, Dayton, Ohio. It was pointed out that neither electronic methods, lighting methods, or thermal methods alone offers the solution to the problem. The solution is not the use of one of these aids; it is the intelligent application of two or more of these devices, each designed to work with the other. The Army Air Forces established a test program at Newark Army Airfield in order to investigate equipment failures under certain

Attending a meeting of the AIEE publications committee during the Middle Eastern District meeting are (clockwise around table) AIEE Secretary H. H. Henline (F '43), C. F. Wagner (F '40), Editor G. R. Henninger (F '43), Chairman B. M. Jones (F '42), H. H. Race (F '39), R. K. Honaman (F '36), and AIEE President B. D. Hull (F '39)

conditions. These tests showed that pilots making instrument approaches under actual adverse weather conditions apparently react so as to deviate materially from the ideal approach path; that the lighting equipment procured under a wartime emergency basis was designed with too restricted a distribution to be effective with such approach deviation; and that present-day transport aircraft are designed structurally so as to impose blind areas making the development of suitable lighting equipment more difficult. In order to conduct further tests and to initiate new developments, a new location for the test program had to be found. An attempt was made to secure a test base in an area where air traffic was not a problem, where unfavorable weather was assured, and where the test program could be controlled rigidly. The Army Air Forces joined the Bureau of Aeronautics, Navy Department, in establishing the Arcata Project at the joint Army-Navy-Civil landing aids experiment station at Arcata, Calif. A description of the test station and test procedures used there was described. The test results obtained at the landing aids experiment station during the fog season of 1946 was highly successful, a total of 92 successful approaches having been made during both day and night fog conditions with visibility ranging down to 400 feet. These were made between the period from August 1946 to November 1946. Among the conclusions based on these tests were that the location of an airport with respect to the center of the city itself should not be the deciding factor if that selection is made at the expense of a needed facility. For example, an airport having its principal approach over water with no area for electronic or visual approach aids ultimately would be discarded for one that can have all the essential aids. Electronic and visual aid must be designed and installed as a correlated installation. Finally, control procedures must be developed to reduce stacking time and to expedite the approach procedure.

AIRPORT LIGHTING

The necessity for providing elevated high-intensity runway and approach lights as an aid during low visibility conditions, both day and night, has been recognized generally. Prewar and postwar developments along these lines were cited in a paper called "Airport Runway and Approach Lighting," by G. M. Kevern (A '40) of the Air Matériel Command, Wright Field, Dayton, Ohio. The provision of high-intensity runway and approach lights of the latest type results in a 10,000 per cent increase in power consumption per runway. Some notable improvements in airport lighting were cited. Boundary lights and runway flood lights have been abandoned in favor of adequate runway marker lights. The fact that high candlepowers are needed during low visibility conditions and that brightness levels as low as one per cent are needed during clear dark nights, has been recognized. Necessary brightness control equipment has been developed. Elevation of runway marker lights above grass, dirt, and snow, has been recognized as being necessary. There has been an increase in runway lighting power requirements from 2 to 16 kw for a 6,000-foot runway. Approach lighting requirements per approach zone have increased from about one to 200-kw. Finally, it has been recognized that low visibility landings cannot be made safely by electronic aids alone, but that high-intensity approach and runway lights must be used to provide last minute visual contact. It was predicted that there would be a widespread use of elevated runway marker lights; that series circuits would be used with an individual 6.6/6.6-ampere isolating transformer to feed each of the elevated runway lights; and that the use of high-intensity incandescent approach lighting systems in all approach zones in which instrument approaches will be made would become standard practice eventually.

CORONA CORRECTION

The use of modern radar equipment in aircraft has introduced high voltages which have resulted in corona and flashover problems. One of the most serious sources of disturbances are the bushings associated with such components as transformers and capacitors. A method of solving this problem by the use of semiconducting coatings was described in a paper called "High-Altitude Flashover and Corona Correction on Small Ceramic Bushings," by W. W. Pendleton (M '43) of the Westinghouse Electric Corporation, East Pittsburgh, Pa. Among the possible methods for improving the corona and flashover behavior of ceramic bushings are design and modification of bushings, pressurization, shielding and air exclusion, and grading of stress concentrations. The paper was concerned primarily with the grading of the stress concentrations by a semiconducting coating with a resistivity of about 3,000 megohms per square applied to the external ceramic surface of the bushing. It was found that by this method, very small bushings could be made essentially free from electrical disturbance up to flashover voltage for high altitudes and therefore the flashover itself could be raised appreciably. The initial electrical disturbance was detected by a sensitive-oscilloscope method which showed that this disturbance occurred at voltages far below the visual corona point. Tests indicated that within the voltage limit of 5,000 peak volts no one other method can offer the advantages associated with the stress-grading method. This method allows the use of very small bushings, saving space and weight; it entails only slight additional cost; it does not require auxiliary equipment; and it requires no design changing. Even in the range from 5,000 to 10,000 peak volts this method, if used with pressurization, may prove practical.

Air Transportation Sessions Feature Developments and Recent Projects

Two air transportation technical sessions, one on general development and the other on recent projects, were held during the Middle Eastern District meeting, in Dayton, Ohio. The general development group of papers covered the progress made in electric equipment for aircraft. The recent project group of papers were concerned mainly with newer developments in the industry, particularly those involving the power supply of aircraft.

General Development

The general development group of papers of the two air transportation technical sessions were presented Tuesday afternoon, at a session presided over by W. T. Harding (A '44). Four technical papers and one conference paper were presented on a variety of subjects.

ELECTRIC SYSTEMS

A survey of the development of electric systems for aircraft, and of the status of electric auxiliary power systems and equipment at the present time, was presented in a paper called "Electricity Aloft" by T. J. Martin (M '45) of Jack and Heintz Precision Industries, Inc., Cleveland, Ohio. The author cited a few early developments of aircraft auxiliary power going as far back as the year 1882. It was then that Gaston Tisandier used an electric motor, powered by a storage battery, to drive a propeller on a balloon. Rotating at 180 revolutions per minute, the 2-bladed propeller pulled the balloon through the air at nearly seven miles per hour. Several World War I developments were mentioned also. The period from World War I till World War II was covered more thoroughly, touching on various developments in d-c and a-c power systems for aircraft. Mention also was made of some British developments during this period. The present aircraft electric power system was described and some remarks were made regarding the possibility of using gas turbine power plants in aircraft. It was mentioned that a unit being built for the Army Air Forces by Continental Aviation Corporation employs a gas turbine operating at 17,000 revolutions per minute to drive a 2-pole 62.5-kva alternator at 24,000 revolutions per minute through gearing. In speculating about future possibilities in the use of electricity in aircraft, the author cited the classic prediction that electricity would be used to transmit power from the engines to the propellers, much in the fashion of the modern Diesel electric locomotive. This idea has provoked vast amounts of speculation and discussion, and many advantages are claimed for such a system.

CONSTANT SPEED DRIVE

A differential-type hydraulic transmission wherein only the torque represented by the difference in speed between the main aircraft engine and the 400-cycle alternator is transmitted by hydraulic pumping and motoring action, was described in a conference paper, "A Constant Speed Drive for Aircraft Alternators," by L. H. Schuette and R. Chizanowski, both of Sundstrand Machine Tool Company, Rockford, Ill. To permit successful parallel operation of alternators and equality of load division between them under various conditions of engine acceleration and load, the drive requires a governor. The governor takes its speed signal from the output shaft of the drive and its load signal from the alternator to position a control valve. This, in turn, regulates the hydraulic system to give the desired output speed. The transmission has a rating of 50 horsepower at 6,000 revolutions per minute output when supplied with input speeds of 3,600 to 9,000 revolutions per minute. At input speeds of 2,400 to 3,600, the available power output of this drive decreases proportionately with the decrease in input speed. Maximum over-all efficiencies of 88 per cent at full load are attained under normal cruise conditions when the input speeds are between 4,500 to 5,500 revolutions per minute.

ELECTRIC TRANSMISSION

G. C. Crom of the Air Matériel Command at Wright Field, Dayton, Ohio, presented an interesting paper on the subject of an electric transmission means of delivering power from an engine to the propellers on an aircraft. His paper was called "Electric Drive for Aircraft" and approached the problem from an engineering point of view. The advantages of electric power transmission were discussed; flexibility, reliability, ability to shut down prime movers, and lessened drag. The main disadvantage seems to be weight, and the author concluded that the electric drive system can be used only on very heavy long-range bombers, having a wide power range in their operation. An electric drive is too heavy to be used on small aircraft except where the flexibility resulting from its use can be shown to overcome the resulting weight increase. An outline of an acceptable airplane and the calculations of fuel savings resulting from electrical operation on a given flight plan were given. These indicated that it is possible to save enough fuel to cancel out the extra weight of the electric drive.

CAPACITANCE-TYPE FUEL GAUGE

The search for a fuel measurement system more suitable for use on present-day and future aircraft than the conventional float-operated gauge, has led to the investigation of the capacitance-type gauge. One of these systems was described in a paper called "A Capacitance-Type Fuel Measurement System for Aircraft," by D. B. Pearson (A '41) of the General Electric Company, West Lynn, Mass. The system employs the usual varying-dielectric capacitor whose capacitance is a function of the quantity of fuel in the tank as a primary detector. The capacitance-to-current conversion is accomplished by an oscillator controlled by the capacitors in the fuel tank. The direct current drawn by the oscillator varies with fuel quantity. A second oscillator also is used, and here the direct current drawn is independent of fuel quantity. Visual indication of fuel quantity is obtained with a conventional indicator which measures the ratio of these two direct currents.

CONSTANT FREQUENCY GENERATOR

Although d-c power supplies have been generally acceptable in the past for aircraft, the increased and more diversified loads being contemplated make the use of a-c power systems very favorable. However, this requires the maintenance of essentially constant frequencies over a wide range of speed variation. The paper, "A Variable Speed Constant Frequency Generator," by C. F. Roys (M '45) of Syracuse University, Syracuse, N. Y., and J. Nader (A '43), and N. Scotts, both of Eicor, Inc., Chicago, Ill., described the means of obtaining constant frequency over a wide speed range. The paper was concerned chiefly with the theoretical aspects of the problem and gave the basis on which a single-phase or a polyphase generator could be built whose frequency could be controlled and kept independent of speed, and whose general characteristics would be similar to those of a d-c generator. It was pointed out that although the frequency of either a synchronous or induction generator is dependent upon speed, yet the frequency observed at the brushes of a commutator-type rotor is the same as the stator frequency. This is the principle utilized in a-c series motors, variable-speed polyphase motors, and the Hull generator. This principle was used as the basis for the generator the paper described. Topics discussed included generated voltage, compensating windings, special problems in commutation, self-excited operation for single-phase and 3-phase units, voltage regulation, parallel operation, motor operation, and compounding.

Recent Projects

Three technical papers and two conference papers comprised the recent projects portion of the two air transportation sessions, which were held Wednesday morning, and was presided over by K. R. Smythe (M '44). Most of these papers concerned themselves with electric power systems of the aircraft.

PROTECTIVE SYSTEMS

A survey of the protective requirements of an aircraft electric power system was described in a paper called, "Aircraft Electric Power Protective Systems," by B. O. Austin (M '43) of the Westinghouse Electric Corporation, Lima, Ohio. In the analysis of protective system developments, consideration must be given to parallel operation, electrical faults, over-voltages, generator over-

temperatures, positive opening through the use of dual contactors, and no battery operation. The differential current relay was described as a device that offers full protection at low as well as high currents. These relays fundamentally consist of two straight conductors surrounded by a magnetic circuit of the proper length and proportion to provide a device having an actuated electrical contact which is operated when the current in the two conductors is unbalanced 100 amperes or more. These relays are located in the main power circuit so that they will function to eliminate the fault by interrupting the proper control circuit for the purpose. The outstanding advantage of such a protective system is that it is responsive to fault conditions only and is not affected by transient power requirements. The co-ordination of timing with other apparatus such as the reverse current cutout is not required. Environmental conditions are not critical with this type of apparatus. For a-c systems, the method of procuring differential protection differs in that instead of parallel conductors being in a common magnetic circuit, current transformers are used to surround the lead. An unbalanced current in the leads will cause voltage from the secondary winding of the transformers, thus operating the necessary control devices to clear the fault.

ELECTRIC SYSTEM TESTING

A paper justifying the increased emphasis placed on testing as a direct aid to design was called "Aircraft Electric System Testing," and was presented by P. H. Merriman of the D. M. Steward Manufacturing Co., Chattanooga, Tenn. Increased complexity of systems and operating requirements, necessary use of new and untried designs and components, increased dependence on the electric system for safe operation, fire hazards due to larger generating capacity, the need to evaluate accurately the hazards inherent in weight reduction measures, the desirability of working out design problems and service aspects of the system in advance of construction, and the frequent lack of time for complete engineering were offered as the reasons justifying increased test costs on aircraft electric systems. A test program was offered that would assure sound design and minimum over-all cost and the elimination of service failures traceable to design shortcomings. Three steps in the program were suggested: a component test in which the individual parts of the complete system are evaluated as discrete items to establish conformance with the requirements; a mark-up test in which each subsystem, and sometimes the complete system, is set up and tested under laboratory conditions, approximating as closely as possible the installation in the aircraft; and a ground and flight test in which each subsystem is tested separately and together in the aircraft under operating conditions as a final check and verifications of the preceding steps. These three steps were embodied in the engineering test program. A brief outline of a production testing program also was included.

AIRCRAFT INVERTERS

Though it generally is recognized in the aircraft industry that the use of an inverter as a source of constant frequency a-c power, is not the most efficient way of obtaining a-c power, the present inverters are the only means of obtaining such power in military or commercial aircraft. This was the thesis of a conference paper called "Inverters and Inverter Systems for Aircraft" presented by S. Zak (A '46) of the Engineering Division of Wright Field, Dayton, Ohio. The nature of several basic problems that must be taken into consideration in the design of inverters, was outlined, including such problems as wave form regulation transients, voltage and frequency regulation, radio noise, phase balance, weight, and climatic conditions. The various types of inverters in general use were described. Voltage and frequency controls also were covered. It was pointed out that the Army Air Forces and commercial industry are concentrating toward designing direct-engine-drive variable-speed constant-frequency alternators. However, at the present time, inverters, it was said, are the only means of obtaining a-c power practically.

PROPELLER DE-ICING

Ice accumulations on aircraft propellers can affect flight safety through reductions in propeller efficiency. An electrical means for removing these ice accumulations was described in a conference paper called "Electrical De-icing of Aircraft Propellers," by J. H. Sheets (A '46) and E. J. Sand, both of Curtiss-Wright Corporation, Caldwell, N. J. It has been found possible, it was pointed out, to use electric heating elements cemented to the blade leading edges of the propellers as a means for ice removal. The electric de-icing system has been developed to a point where satisfactory performance is being obtained on current installations. The normal aircraft 28-volt d-c power supply is used with suitable slip rings and brushes for current transfer between the engine nose and the rotating propeller structure. Power requirements are in the order of 3,500 watts per propeller with cyclic energization of propellers on multiengine aircraft to limit the power required from the aircraft system. Blade heating elements are being molded from synthetic rubber compound using both conductive rubber and resistance wire heaters. It was pointed out that because it has been difficult to interpret available meterological data into design specifications for heating intensity, heating area, and cycle time in order to insure satisfactory de-icing performance under all conditions, further work is considered necessary to establish optimum specifications.

WINDOW DE-ICING

Another aircraft icing problem is the formation of ice on the windshield of an airplane which usually results in complete loss of vision within a very few seconds after icing conditions have been encountered. The method in which this problem is being solved was cited in a paper called "Control of Power Systems for Aircraft Window De-icing" by C. L. Mershon (A '47) of the Westinghouse Electric Corporation, Lima, Ohio. A new type of heater formed by a transparent electrically conductive coating on the surface of the glass was described. The power and control limitations of a power supply for this type of electric de-icing equipment was discussed in some detail. It was pointed out that the window panel configuration, location, and angle with respect to the air stream, have much bearing

Among those enjoying the well-stocked banquet table at the smoker-banquet are Editor Henninger (far left), H. F. Rempt (A '43) of Burbank, Calif. (third from left), AIEE President Hull (second from right), and (looking over Mr. Hull's shoulder) Robin Beach (F '35)

on the power requirements. These requirements may range from 500 to 3,100 Btu per hour per square foot (147 to 910 watts per square foot) according to specifications of aircraft builders and operators. Tests have indicated that hot spot conditions may develop when energy is being applied to the windows at a high rate. These are more serious than when the energy is being supplied at a lower rate when ambient temperature and air conditions are such that the heat is not dissipated rapidly from the windows, even though the energy is applied for a shorter duration. It would seem desirable to operate the window heaters from a source which would supply maximum power for severe conditions and an intermediate power for average heating requirements. Although a simple on-off control is satisfactory for some types of windows, a 3-position temperature control scheme appears to minimize the possibility of damaging the windows by applying energy to the window heaters at a comparatively low rate under average conditions. Application of maximum power is limited to extreme temperature conditions and when power first is applied to cold windows. It was pointed out that only after considerable operating experience has been accumulated on these installations, will sufficient data be available to determine the most effective method for controlling the window heaters.

Variety of Subjects Discussed at Industrial Electronics Session

Two technical papers and four conference papers comprised the industrial electronics session which was held Wednesday morning during the Middle Eastern District meeting. W. C. Osterdrock (M '41) presided over the session which included a wide range of papers on the use of electronic equipment in industry, from electronic equipment for the rubber industry to timing circuits in resistance welding controls.

RUBBER INDUSTRY CONTROLS

How electronic equipment has made important contributions to several phases of the rubber industry was outlined in a paper called "New Developments in Electric Equipment for the Rubber Industry," B. J. Dalton (A '40) of the General Electric Company, Schenectady, N. Y. Various electronic controls that are being used currently in the rubber industry were described. Some of these were a tuber conveyer system using electronic control for weight regulation, and for co-ordination of the speed of several conveyers; a large, electronically co-ordinated calender train used for continuous processing of tire fabric; and a modified version of a standard packaged electronic motor control which is applied to a tire-building machine. It was pointed out that operating experience with literally thousands of electronic drives installed in many industries not only in the United States, but also abroad, have dispelled doubts and fears regarding the suitability of electronic equipment for industrial use, in fact, positive advantages have been realized. In general, the equipment can be taken for granted, maintenance is relatively simple, and maintenance records are exceptionally good. In the discussion that followed the presentation of the paper, a point was raised about the method of making a quick stop in case of an emergency. It was stated that it was necessary to use air power in addition to electric power to stop the equipment. The author replied that dynamic braking with a current limiter was used and performed satisfactorily. It also was asked whether speed ratios greater than five to one could not be used with fixed voltage. The author replied that it was a matter of economics, for such ratios variable voltage was cheaper.

DIRECT-COUPLED AMPLIFIER

An amplifier embodying circuits giving d-c amplifier characteristics was described in a paper called "Direct-Coupled Oscillograph Amplifier" by D. R. Christian (A '47) of the Brush Development Company, Cleveland, Ohio. The unit was designed primarily to operate in conjunction with a direct-inking oscillograph. The active element of this device, the pen motor, consists of a coil mounted in the field of an extremely powerful permanent magnet. A lightweight pen is attached to the coil by means of a compliant member. Ink is fed through the pen by capillary action, making an instantaneous permanent record on a moving paper chart. The sensitivity of the pen motor is such that 0.94 volt applied to the coil terminals results in one chart-millimeter displacement of the pen. To obtain the damping necessary for the faithful reproduction of transients, it is necessary to drive the pen motor from a low impedance source. In order to increase the sensitivity of the pen motor, and at the same time take full advantage of its ability to record d-c signals, a direct-coupled amplifier of the proper characteristics is absolutely necessary. To overcome the slow random variation in the output of the amplifier commonly known as "drift", balanced circuit arrangements were used employing nearly identical tubes. The tubes were aged by operating them for 1,000 hours at a plate current of about 50 microamperes to give drift-free operation. Circuits were so arranged that the drift in one tube is canceled by the drift in the other. Fundamentally, a bridge-balanced circuit was used in which all the variables in the amplifier, including supply voltages and tube characteristics, are balanced against similar variables in a second arm of the bridge. Two such series-balanced stages are followed by three stages containing degenerative feedback and a cathode follower circuit to work into the pen motor impedance. The feedback circuit also provides high-frequency compensation for the pen motor. A calibration circuit is included in the amplifier so that the pen deflection of the oscillograph element can be correlated accurately to the input voltage. Filament power for the first two stages is obtained from a regulating transformer, and the remaining filaments are operated from the filament winding of the power transformer. The d-c power supply is regulated by means of voltage regulator tubes. The normal sensitivity of the amplifier used with the magnetic pen motor recorder is one millivolt per one chart-millimeter of displacement of the pen. Its frequency response is essentially uniform from zero to 100 cycles per second.

PLATE DISSIPATION

A fundamental approach to the problem of measuring plate dissipation of a vacuum tube was described in a paper called "A Calorimetric Method for Direct Measurement of Plate Dissipation," R. T. Squier of the Minneapolis-Honeywell Regulator Company, Minneapolis, Minn. A circuit where one of two tubes in a discriminator arrangement supply the power to drive a 2-phase induction motor was cited as an example of a case where the plate dissipation of the tube cannot be determined accurately by direct measurement. The current through the operating tube is not directly obtainable because it is intermittent and its wave form is indeterminate. A method was described in which a calorimeter was used to obtain a multiplying factor that can be applied to the product of meter values of current and voltage to determine the power output. The calorimeter was made up of two concentric cylindrical cans suitably insulated from each other, and olive oil was used as the heat collecting agent because of its constant specific heat and good electrical insulating qualities. An automatic stirring device insured continuous circulation. In order to check the accuracy of the calorimeter, a test was run operating only the filament of a tube with direct current, the voltage and current being measured with standard instruments. A time versus temperature curve was made, and a portion of this curve was used from five degrees below ambient temperature to five degrees above, to determine the heat output of the tube. The result was compared with the measurements made by the standard instruments and an error of 0.7 per cent was found.

CURRENT DISTRIBUTION

In the rapid heating of relatively poor thermal conductors by high-frequency dielectric heating, the initial distribution of temperature is found to follow the current distribution. Certain organic substances such as food have electrical conductivities which cannot be neglected in finding the current distribution. A paper describing the investigation of the distribution of current in cylindrical samples of such semiconductors was "Current Distribution in Semiconductors Heated by High-Frequency Currents," F. C. Weimer (A '41) of Ohio State University, Columbus, Ohio. Starting with Maxwell's equa-

tions, the general equation for current distribution was developed. For cylindrical samples with axial current flow the current density is proportional to $J_0\ (kr)$, where r is the distance from the axis to the point in question, and k is a complex constant whose angle is half the loss factor angle of the material. When these results are plotted graphically they show a gradual transition from the "standing-wave" distribution of poor electrical conductors to the "skin-effect" distribution for good electrical conductors.

THYRATRON CONTROLS

"A Thyratron-Controlled Automatic Welding Head" was a conference paper by R. J. LaPlante and G. H. Sett (M '38) of the University of Illinois, Urbana, Ill., describing a unit that accurately controlled welding arc voltage. The arc voltage is maintained constant by adjusting the rate at which the welding electrode is fed to the arc. A phase shifting circuit controls a thyratron's anode current which also is the armature current of a separately excited d-c motor. The circuit is arranged so that the welding electrode can be moved in either direction giving complete control over the arc voltage. Some of the problems which arose in the application were cited, such as the distortion of the thyratron grid-voltage wave form, the false operation of one of the thyratrons because of the back electromotive force of the motor and armature self inductance, and excessive hunting because of high sensitivity. The solution to these problems was given and the resulting control was made simple, stable, and quickly responsive to such changes in arc length.

TIMING CIRCUITS

Several basic timing circuits as used in resistance welding controls were described in a conference paper called "Timing Circuits in Resistance Welding Controls," B. Sussman of the General Electric Company, Schenectady, N. Y. Modern high-speed welding processes require proper timing of the sequences in a welding operation in order to assure high quality welds. Electronic timing circuits can accomplish this easily, cheaply, and accurately. These timing circuits may be used to control "squeeze time," "weld time," "hold time," and "off time" for a simple resistance spot weld. In addition, they may consist of special timing circuits to furnish "forge-delay time," "preheating time," "post-heating time," or "tempering time." The time-delay range may vary from one cycle to several hundred cycles. Regardless of the function of the particular timing circuit involved, it was pointed out that the circuits are fundamentally the same. A capacitor charging or discharging through a variable resistor furnishes the means of time delay. Using the basic equations for the voltage across the capacitor charging or discharging through a resistor the basic timing circuits for sequence controls can be developed. Several industries require 350 to 400 welds per minute which is one weld every ten cycles. For this type of application, a high-speed sequence control has been developed capable of 400 sequences a minute. Several recommendations to designers of timing circuits for welding controls were made including care in the selection of resistors and capacitors, and that consideration be given to minor fluctuations in line voltage which will affect the timing circuit. Variation in timing circuits due to variations in tube characteristics of the same type of tube and also over the life of a particular tube also were cited as important design considerations.

AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full formal text of a technical paper including discussion, if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

Meetings	Abstracts	PROCEEDINGS Order Forms
Winter	Jan '47, pp 84–93; Feb '47 pp 190–1	Feb '47, pp 33A and 34A
North Eastern District	Apr '47, pp 401–02	June '47, pp 55A and 56A
Summer General	June '47, pp 607–14; July '47, p 708	

AIEE Board of Directors Meets in New York City

The regular meeting of the AIEE board of directors was held at Institute headquarters, New York, N. Y., Monday, August 11, 1947.

Recommendations adopted by the board of examiners at meetings held June 19 and July 17 were reported and approved. The following actions were taken upon recommendation of the board of examiners: 6 applicants were transferred and one was re-elected to the grade of Fellow; 91 applicants were transferred and 57 elected to the grade of Member; 386 applicants were elected to the grade of Associate; 283 Student members were enrolled.

Disbursements from general funds were reported by the finance committee and approved, as follows: June 1947, $50,324.40; July 1947, $68,085.49.

Upon recommendation of the committee on Student Branches, authorization was given for the establishment of a Student Branch of the Institute at Wayne University, Detroit, Mich.

Appointment of the following Institute representatives was approved, as recommended by the Standards committee:

Raymond L. Witzke as an AIEE representative on Sectional Committee C63, Radio Electrical Co-ordination.

James H. Foote as AIEE representative and chairman of AIEE delegation on Joint Committee on Insulation Co-ordination.

R. O. Fehr as AIEE representative on Sectional Committee B46, Classification and Designation of Surface Qualities, succeeding W. Mikelson, resigned.

W. E. Rushlow as an additional AIEE representative on Sectional Committee C62, Lightning Arresters.

H. S. Vassar as AIEE representative on Sectional Committee J6, Rubber Protective Equipment.

A. E. Silver as an additional AIEE representative on Sectional Committee C57, Transformers, Induction Regulators, and Reactors.

The following AIEE meetings were authorized, upon recommendation of the committee on planning and co-ordination:

1948 Great Lakes District meeting, Des Moines, Iowa, April 1, 2, and 3.

1949 Midwest general meeting, Cincinnati, Ohio, in the week beginning October 16.

Scopes of the 12 technical committees in the power group were approved as adopted by the group co-ordinating committee on July 11, 1947 (*EE, Oct '47, pp 1006–11*).

Upon recommendation of the groups concerned and endorsement by the committee on planning and co-ordination, changes in names of certain technical committees were authorized as indicated in the following:

Former Name	New Name
Industry group:	
Machine tools, material processing, and fabrication	general industry applications
Mining, metal forming, and boiling	mining and metal industry
Industrial control devices and equipments	industrial control
Power group:	
Power substations	substation committee
Power rotating machinery	rotating machinery committee
Power transformers and regulators	transformer committee
Power generation committee	no change in title
Power system operation	system engineering committee
Power transmission and and distribution	transmission and distribution committee
Insulated power cables	insulated conductor committee
Power protective devices	protective devices committee
Power switchgear	switchgear committee
Power relays	relay committee
Power systems application of carrier current	carrier current committee
Power converters—electronic	electronic power converter committee

A revision, dated July 30, 1947, of the rules for the award of Institute prizes was approved as submitted by the special committee to review the practices in the award of AIEE prizes, to become effective as of

January 1, 1948. The revised rules provide for the following prizes:

1. *Institute prizes* (certificate of award and $100 in cash), as follows:

(*a*). Best paper prize in each of four classes: design, operation, research, and education and general interest

(*b*). Branch paper prize.

2. *District Branch competition prize* (certificate of award and $25 in cash).

3. *Branch prize* (certificate of award and sum of $10 plus an allowance of seven cents per mile one way to the District competition).

4. Competitions in Districts and Sections arranged locally, appropriate to local conditions. If handled on an annual basis in general conformity with the procedure outlined for national and Branch competition, the District or Section officers may arrange with the secretary of the Institute to issue suitable certificates of award.

The following actions were taken by the directors, as required by the bylaws of the committees concerned:

Edison Medal committee: Confirmed the appointment by the president of H. S. Osborne, Marvin W. Smith, and H. A. Winne as members of the committee for the term of five years beginning August 1, 1947, and the reappointment of S. M. Dean as chairman for the year 1947–48.

Elected from its own membership, to serve for the 2-year term beginning August 1, 1947, W. L. Everitt J. F. Fairman, and A. C. Monteith.

Charles LeGeyt Fortescue Fellowship committee: Confirmed the appointment by the president of H. N. Muller and H. P. Sedwick as members of the committee for the term of three years beginning August 1, 1947.

Lamme Medal committee: Confirmed the appointment by the president of F. E. Harrell and J. B. Thomas as members of the committee for the 3-year term beginning August 1, 1947.

The directors reviewed the special (temporary) committees and representatives of the Institute, discharging some and continuing others. Standing representatives were appointed for the year beginning August 1, 1947 (*EE, Oct '47, p 1035*). The following local honorary secretaries were reappointed for the 2-year term beginning August 1, 1947: Richard H. Bowles for Brazil, A. P. M. Fleming for England, R. D. Neale for New Zealand, and Edy Velander for Sweden.

Upon request of the District officers, in view of the fact that the 1948 AIEE summer general meeting will be held in the city of Mexico (in District 7), it was voted that the South West District meeting scheduled for April 21–23, 1948, be canceled.

The meeting was adjourned after an expression of the directors' appreciation of the very exceptional service to the Institute performed by its president for the very successful year just ended.

Present at the meeting were

President B. D. Hull, Dallas, Tex. Past Presidents J. Elmer Housley, Alcoa, Tenn.; W. E. Wickenden (deceased) Cleveland, Ohio. Vice-Presidents J. H. Berry, Norfolk, Va.; G. W. Bower, Haddonfield, N. J.; O. E. Buckley, New York, N. Y.; D. I. Cone, San Francisco, Calif.; R. F. Danner, Oklahoma City, Okla.; E. W. Davis, Cambridge, Mass.; I. M. Ellestad, Omaha, Nebr.; D. G. Geiger, Toronto, Canada; T. G. LeClair, Chicago, Ill. Directors P. L. Alger, Schenectady, N. Y.; W. L. Everitt, Urbana, Ill.; J. F. Fairman, New York, N. Y.; R. T. Henry, Buffalo, N. Y.; M. J. McHenry, Toronto, Canada; A. C. Monteith, East Pittsburgh, Pa.; J. R. North, Jackson, Mich.; D. A. Quarles, New York, N. Y.; Elgin B. Robertson, Dallas, Tex.; Walter C. Smith, Palo Alto, Calif.; E. P. Yerkes, Philadelphia, Pa. Treasurer W. I. Slichter, Schenectady, N. Y. Secretary H. H. Henline, New York, N. Y.

Future AIEE Meetings

Midwest General Meeting
Congress Hotel, Chicago, Ill., November 3–7, 1947

Winter General Meeting
William Penn Hotel, Pittsburgh, Pa., January 26–30, 1948

Great Lakes District Meeting
Des Moines, Iowa, April 1–3, 1948

North Eastern District Meeting
New Haven, Conn., April 28–30, 1948

Summer General Meeting
Mexico, Federal District, Mexico, June 21–25, 1948

Midwest General Meeting
Milwaukee, Wis., October 18–22, 1948

Southern District Meeting
Birmingham, Ala., November 3–5, 1948

PERSONAL ● ● ● ●

Clifford Ray Beardsley (A '08, M '20, F '30) of the Consolidated Edison Company of New York (N. Y.) Inc., has been appointed 1947–48 chairman of the AIEE committee on Members-for-Life Fund. Born in Bridgeport, Conn., December 19, 1885, he received the degree of bachelor of philosophy in electrical engineering from Yale University in 1905. From 1905 to 1911 he served in various capacities with the General Electric Company in New York, and New Haven, Conn., and in 1911 became sales agent for the United Illuminating Company, Bridgeport. He joined Fred T. Ley and Company, Springfield, Mass., as electrical engineer in 1918. He was associated with the Brooklyn (N. Y.) Edison Company from 1923 to 1939 as electrical construction engineer, assistant to the superintendent of distribution, and superintendent of distribution. Transferred to the Consolidated Edison Company, he became manager of the contract controls and inspection department and in 1942 manager of station construction and shops. He was given a wartime leave of absence in 1942 to act as assistant to the commissioner of the Department of Commerce of the City of New York. Exceedingly active in AIEE committee work, Mr. Beardsley has been chairman of the committees on Institute policy, legislation affecting the engineering profession, registration of engineers, and a special committee on the model registration law. He also has served on the Edison Medal and technical program committees. He was a member of the AIEE board of directors for 1937–41. Mr. Beardsley is the author of a number of technical papers.

Titus George LeClair (A '24, M '29, F '40) supervising development engineer, Commonwealth Edison Company, Chicago, Ill., has been appointed chairman of the AIEE professional group co-ordinating committee for 1947–48. Born in Superior, Wis. on August 26, 1899, he received a bachelor of science degree in electrical engineering from the University of Idaho in 1921. From 1922 to 1923 Mr. LeClair was a student engineer with the General Electric Company, Schenectady, N. Y., and in 1923 he was employed as cable engineer with the Commonwealth Edison Company, Chicago, Ill. In 1924 he was promoted to substation field engineer, and became engineer of system protection in 1927. He subsequently became a staff engineer in the chief electrical engineer's office in 1930, and in 1932 was appointed development engineer; he was promoted to his present position in 1936. Mr. LeClair has presented various papers to AIEE conventions and Section meetings, and has contributed articles to technical magazines. He also has several relaying and control inventions to his credit. He has taken an active part in the AIEE, serving on many committees including: protective devices, 1931–45, of which he was chairman in 1942–43; legislation affecting the engineering profession, 1940–41; land transportation, 1941–42; Edison Medal, 1942–44; Standards, 1942–43; technical program, 1942–43; award of Institute prizes, 1942–43; special committee on registration of engineers, 1942–47, of which he was chairman for 1946–47; planning and co-ordination, 1943–47; constitution and bylaws, 1944–47; Student Branches, 1945–46; and Lamme Medal, 1946–47. Mr. LeClair was on the board of directors 1941–45; the board of examiners, 1943–44; and the AIEE's representative to the National Bureau of Engineering Registration advisory board, 1946–47. He was also vice-president of the Great Lakes District (5), 1946–47. He has been a member and trustee of the Western Society of Engineers, a member of the Illinois Society of Engineers, and a director of the Illinois Engineering Council. Recently he was elected chairman of the Washington Award Commission for 1947–48.

James Ferdinand Fairman (A '20, M '27, F '35) vice-president in charge of production and operation, Consolidated Edison Company of New York (N. Y.) Inc., has been appointed chairman of the AIEE administration co-ordinating committee for 1947–48. Born on April 8, 1896, in Big Rapids, Mich., Mr. Fairman was graduated from the University of Michigan with a bachelor of science degree in electrical engineering in 1918, and with a master of science degree in 1921. He joined the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) East Pitts-

C. R. Beardsley

T. G. LeClair

J. F. Fairman

burgh, Pa., in 1919, as a student in that company's graduate course. After that Mr. Fairman held a position as an instructor in electrical engineering at the University of Michigan, Ann Arbor, and in 1922 he was made an assistant professor in electrical engineering. In 1925 he was employed by the Brooklyn, N. Y. Edison Company, Inc., as an assistant outside plant engineer. In 1926 he became outside plant engineer, and later in that same year assistant electrical engineer. In 1932 he was made electrical engineer of the Brooklyn Edison Company, and following the merger of the various companies into the Consolidated Edison Company of New York (N. Y.) Inc., he became electrical engineer for the System. In 1940 he was elected assistant vice-president for design, inventory, purchasing, and stores, and in 1946 he was elected vice-president in charge of production and operation. Mr. Fairman was AIEE vice-president for the New York City District (3), 1944–46; chairman of the New York Section, 1940–41; a member of the board of examiners, 1941–44; and a member of the board of directors, 1946–47. He has served on many AIEE committees, including planning and co-ordination, of which he was the chairman, 1945–47; technical program, 1941–47; executive, 1944–47; finance, 1944–46; education, 1941–42; and Institute publicity, 1946–47. Since 1938 he has been an AIEE representative on the Engineers' Council for Professional Development. He has held the office of president of the New York State Society of Professional Engineers, and is also a member of Tau Beta Pi and Sigma Xi.

Max Jacob Steinberg (A '24, M '32) division engineer, system engineering department, Consolidated Edison Company of New York (N. Y.) Inc., has been appointed chairman of the AIEE power co-ordinating committee for 1947–48. Born on April 15, 1900, in Russia, he received a bachelor of science degree in 1922 and a master of science degree in 1923 from the Massachusetts Institute of Technology. In 1928 Mr. Steinberg received a bachelor of laws degree from St. Lawrence University. He was employed in testing generating equipment by the Brooklyn (N. Y.) Edison Company Inc., after he was graduated from the Massachusetts Institute of Technology in 1923, later in general engineering in connection with system operation, and he was appointed to his present position in 1937. He has been a part-time lecturer at New York University and Brooklyn Polytechnic Institute. Mr. Steinberg is a member of the American Society of Mechanical Engineers, has been chairman of the joint AIEE-ASME committee on a Recommended Specification for Prime-Mover Speed Governing, and is a member of the New York State Society of Professional Engineers. Among his AIEE activities are: 1946–47 chairman of the committee on power generation of which he has been a member since 1939; Standards committee, 1946–47; and technical program committee, 1946–47.

Walter R. G. Baker (A '19, M '41, F '47) vice-president, electronics department, General Electric Company, Syracuse, N. Y., has been appointed chairman of the AIEE communication and science co-ordinating committee for 1947–48. Doctor Baker, born in Lockport, N. Y., on November 30, 1892, was graduated from Union College with a degree in electrical engineering in 1916, a degree in mechanical engineering in 1918, and an honorary doctor of science degree in 1935. He joined the General Electric Company's research laboratories in Schenectady, N. Y., in 1917, and in the following year was made managing engineer of the radio department. In 1930, after the formation of the Radio Corporation of America-Victor Corporation, Doctor Baker went to Camden, N. J., to head the radio engineering activities of the new organization, and shortly afterwards became vice-president and general manager of the plant. In 1935 he resumed his connection with the General Electric Company, Syracuse, N. Y., holding the position of managing engineer until 1939 when he assumed his present status. Doctor Baker is the 1947 president of the Institute of Radio Engineers, a director of the engineering department of the Radio Manufacturers Association, chairman of the National Television System Committee and of the Radio Technical Planning Board, and is a member of the National Electrical Manufacturers' Association. Among his AIEE activities are included the following committees; special committee on biographies and talking motion pictures, 1933–41; special committee on postwar planning, 1943–45; electronics, chairman, 1945–47; Standards, 1945–47; and technical program, 1945–47.

Samuel Galloway Hibben (A '34, M '45) director of applied lighting, lamp division, Westinghouse Electric Corporation, Bloomfield, N. J., has been appointed chairman of the AIEE general applications co-ordinating committee for 1947–48. Born on June 6, 1888, at Hillsboro, Ohio, he received his technical education at the Case School of Applied Science where he was graduated with a bachelor of science degree in 1910 and an electrical engineering degree in 1914. After graduation, in 1910, Mr. Hibben joined the MacBeth Glass Company in Pittsburgh, Pa., as an illuminating engineer. In 1914–15 he was an illumination consulting engineer in Pittsburgh, Pa., and in 1915 he became associated with the Westinghouse Electric Corporation, (then the Westinghouse Electric and Manufacturing Company) Bloomfield, N. J., as an illuminating engineer. He has remained with this company since that date except during the years 1917–19 when he served in the Army of the United States in the Corps of Engineers. When the war ended Mr. Hibben was in France where he remained to take a year of postgraduate work at the University of Paris. He rejoined Westinghouse Electric Corporation in 1919, and was appointed branch manager at the Cleveland (Ohio) branch office of the Westing-

M. J. Steinberg

W. R. G. Baker

S. G. Hibben

house Lamp Division. In 1920 he was called to Bloomfield, N. J., to develop a lighting service bureau which was later to become the present commercial engineering department. He became director of applied lighting in 1933. He is a past national secretary and director of the American Illuminating Engineering Society, and has served on the following AIEE committees: production and application of light, 1938–47, chairman 1945–47; Standards, 1945–47; technical program, 1945–47. He has been an AIEE representative to the United States National Committee of the International Commission on Illumination since 1945. Mr. Hibben is also a member of the Society of American Military Engineers, the Engineers' Club of New York, the Montclair Society of Engineers, the Electrical Association of New York, and the London Illuminating Engineering Society.

Charles Evans Kilbourne (A '29, M '37, F '47) designing engineer, motor and generator engineering division, General Electric Company, Schenectady, N. Y., has been appointed chairman of the rotating machinery committee of the AIEE for 1947–48. Mr. Kilbourne was born on April 16, 1906, at Fort Sam Houston, Tex., and was graduated from Virginia Military Institute in 1927 with a bachelor of science degree in electrical engineering, afterwards taking postgraduate study at the Massachusetts Institute of Technology. He was employed in the testing department of the General Electric Company in Schenectady, N. Y., from 1927 to 1929, and then transferred to the a-c engineering department of the same company. Mr. Kilbourne is a member of the New York State Society of Professional Engineers. He was chairman of the AIEE Schenectady Section in 1935, served on the AIEE committee on electric machinery from 1943 to 1945, and was chairman of the test code committee for 1944–45.

Arthur Herbert Frampton (A '21, M '28, F '45) assistant chief electrical engineer, electrical engineering department, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been appointed 1947–48 chairman of the AIEE committee on power generation, of which he has been a member since 1942. Born in Gillingham, Kent, England on May 23, 1899, Mr. Frampton attended Council School of Gillingham and Toronto Central Technical School. He was graduated from the University of Toronto in 1925 with the degree of bachelor of applied science. From 1915 to 1917 he was engaged in general construction and installation work with G. J. Beattie Company, Toronto, Ontario, and then he became associated with the Hydro-Electric Power Commission as a laboratory assistant in practical testing and investigation work. In 1941 Mr. Frampton was coauthor of the paper "The 220,000-Volt System of the Hydro-Electric Power Commission of Ontario" which received the AIEE District 10 prize for the best paper. He is a registered member of the Association of Professional Engineers of Province of Ontario. Mr. Frampton has served on the Toronto Section committee, acting as 1945–46 chairman of that committee, and was secretary for the transfers committee in 1945–46. He was vice-chairman of the power generation committee for 1946–47.

Luke Francis Kennedy (A '37, M '39) relay application engineer, General Electric Company, Schenectady, N. Y., has been appointed 1947–48 chairman of the AIEE carrier current committee. Born in Pittsfield, Mass., on June 11, 1901, he was graduated from Rensselaer Polytechnic Institute in 1922 with an electrical engineering degree. Mr. Kennedy became associated with the General Electric Company in Schenectady in 1923 as a development engineer in the relay section. He transferred to the Philadelphia, Pa., relay section of the General Electric Company in 1928, becoming assistant engineer in 1933. In 1939 he transferred to the General Electric central station department in Schenectady where he since has held his present position. Mr. Kennedy is a member of Sigma Xi. He has been on the AIEE committee on protective devices since 1940, serving as secretary for that group for 1946–47. He has written several technical papers.

George B. Dodds (A '29, M '45) relay protection and section engineer, planning and development, Duquesne Light Company, Pittsburgh, Pa., has been appointed chairman of the AIEE committee on protective devices for 1947–48. Mr. Dodds was a member of this committee from 1940 to 1945. He was born on November 20, 1897, in Pittsburgh, Pa. After graduating from Carnegie Institute of Technology, Mr. Dodds was employed by the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), East Pittsburgh, Pa. In 1918 he was engaged in railway equipment maintenance for the Pittsburgh Railways Company, transferring to a position with the Bell Telephone Company in Pittsburgh in 1919. Mr. Dodds became associated with the Duquesne Light Company in 1922. At first he was engaged in testing and maintenance of automatic substation equipment, and later advanced to his present position. In his work on the AIEE committee Mr. Dodds has participated in preparing standards. He is a coauthor of several technical papers.

Harry John Lingal (A '33, M '41) switchgear and control engineering department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed chairman of the AIEE power switchgear committee for 1947–48. Born on February 27, 1890, in Greensburg, Pa., Mr. Lingal attended schools in Indiana. He taught school from 1910 to 1914, and in 1915 started as a tracer in the engineering department of the Railway and Industrial Engineering Company, Greensburg. Mr. Lingal left the latter employ in 1919, and operated his own machine shop and foundry until 1923 when he joined the Westinghouse Electric Corporation. Mr. Lingal has served on the AIEE committee on protective devices from 1933 to 1947.

Latimer Farrington Hickernell (A '25, M '27, F '34) chief engineer, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., has been appointed 1947–48 chairman of the AIEE. insulated conductor committee. Born on March 22, 1899, at Middletown, Pa., Mr. Hickernell was graduated from Grinnell College with a bachelor of arts degree in 1920. He received a bachelor of science degree in electrical engineering from Massachusetts Institute of Technology, in 1922. After graduation he was a graduate student engineer with the General Electric Company, West Lynn, Mass., until 1923 when he became an instructor in electrical engineering at Iowa State College, Ames. In 1923 he became an assistant investigations engineer for the Commonwealth Power Corporation of Michigan, Jackson. Joining the Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y., as an electrical engineer in 1931, Mr. Hickernell was appointed chief engineer of that organization in 1933. He served on the AIEE power transmission and distribution committee, 1930–42, and has been a member of the board of examiners since 1941. He also has been very active

A. H. Frampton

L. F. Kennedy

G. B. Dodds

on engineering committees of the National Electric Light Association, and is the author of numerous reports and papers.

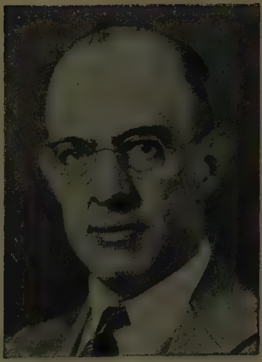
Howard Bascomb Keath (M '26, F '39) manager, transformer engineering division, Wagner Electric Corporation, St. Louis, Mo., has been appointed 1947–48 chairman of the AIEE transformer committee. Born on September 15, 1896, at Salisbury, Mo., Mr. Keath received his bachelor of science degree in electrical engineering from the University of Missouri in 1917. He became affiliated with the Wagner Electric Corporation in 1917, rising subsequently from the position of a student to his present capacity. He is a member of the St. Louis Electrical Board of Trade, National Electrical Manufacturers' Association, and Engineers of St. Louis.

Frank W. Cramer (M '40) electrical engineer, Carnegie-Illinois Steel Corporation, Pittsburgh, Pa., has been appointed the 1947–48 chairman of the AIEE mining and metal industry committee. Born in Johnstown, Pa., on September 24, 1891, Mr. Cramer received his bachelor of science degree in 1914 and his electrical engineering degree in 1919, from Pennsylvania State College. He had been connected with the Bethlehem Steel Company, Johnstown, Pa., and with the Republic Steel Corporation, Cleveland, Ohio, before being associated with the Carnegie-Illinois Corporation. Mr. Cramer served on the AIEE protective devices committee from 1941 to 1945, and has been on the industrial power applications committee of the AIEE since 1944. He is also a member of the Association of Iron and Steel Engineers.

Thomas Oliver Sweatt (A '33, M '44) assistant electrical engineer, Burns and Roe, Inc., New York, N. Y., has been appointed 1947–48 chairman of the AIEE industrial power systems committee. Born at Boone, Iowa, on May 25, 1910, Mr. Sweatt was graduated from Iowa State College with a bachelor of science degree in electrical engineering in 1931, and received his master of science degree in electrical engineering from Purdue University in 1932. From 1932 to the present he has held engineering positions with various companies, becoming affiliated with Burns and Roe, Inc. in 1943. Mr. Sweatt served on the AIEE industrial power applications committee for 1946–47.

Edwin H. Vedder (A '28, M '35) electrical engineer, Westinghouse Electric Corporation, Buffalo, N. Y., has been appointed chairman of the AIEE electric welding committee for 1947–48. Mr. Vedder was born on April 16, 1905, at Milan, Mich. He received a bachelor of science degree in electrical engineering in 1926 from the University of Michigan, and joined the Westinghouse Electric Corporation soon after graduation. Mr. Vedder has served on the AIEE electric welding committee from 1938 to 1946, holding the position of vice-chairman and secretary of this committee for 1946–47, and he has been on the electronics committee since 1945.

H. J. Lingal



F. W. Cramer

T. O. Sweatt

John L. Callahan (A '23, M '35) head, research division, Radio Corporation of America Laboratories, New York, N. Y., has been appointed chairman of the 1947–48 AIEE communications committee, of which he has been a member since 1941. Mr. Callahan was born on December 9, 1898, at Minneapolis, Minn., receiving his early engineering training in Army electrical and signal schools, and later taking a postgraduate course in radio engineering at Sorbonne University. In 1920 he became associated with the engineering department of the Radio Corporation of America in communication research, and in 1930 was made division head in charge of the central office research laboratory. Mr. Callahan is a member of the Radio Club of America, and of the Institute of Radio Engineers. He held the position of secretary of the AIEE New York Section for 1943–44, and was chairman of that Section in 1945–46.

William Russell Brownlee (A '35, M '38) investigations division, Commonwealth and Southern Corporation, Jackson, Mich., has been appointed chairman of the AIEE relay committee for 1947–48. Born in Cleveland, Tenn., on December 1, 1905, Mr. Brownlee attended the University of Arizona from 1923 to 1927, receiving a bachelor of science degree in electrical engineering. He then became connected with Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), East Pittsburg, Pa., transferring in 1929 to a position with the Tennessee Electric Power Company, Chattanooga. Mr. Brownlee is a member of Tau Beta Pi and Phi Kappa Phi. He served on the AIEE committee on protective devices from 1937 to 1942.

J. Eliot McCormack (A '27, M '37, F '44) assistant outside plant engineer, Consolidated Edison Company of New York (N. Y.) Inc., has been appointed 1947–48 chairman of the AIEE system engineering committee. Born on October 22, 1904, in New York, N. Y., Mr. McCormack received his electrical engineering degree in 1926 from the Brooklyn Polytechnic Institute. In July of that year he became associated with the New York and Queens Electric Light and Power Company, Flushing, as a junior engineer, advancing to assistant engineer with that firm in 1927, and finally becoming distribution engineer in 1937. In 1938 Mr. McCormack accepted a position as division engineer with the Consolidated Edison Company, and has remained with that concern up to the present date. He was a member of the AIEE membership committee from 1934 to 1938, and also served on the power transmission and distribution committee from 1944 to 1946.

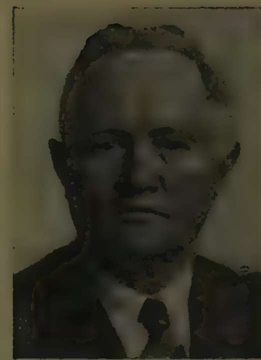
Ernest E. Charlton (A '45) X-ray section head, research laboratory, General Electric Company, Schenectady, N. Y., has been appointed chairman of the AIEE therapeutics committee for 1947–48. Born on December 17, 1890, at Meriden, Iowa, Mr. Charlton received his bachelor of arts degree in 1913 from Grinnell College. He obtained his master of science and doctor of philosophy degrees in 1915 and 1918, respectively, from the University of Illinois, and was awarded a doctor of science degree in 1945 by Grinnell College. He has been employed by General Electric Company since 1920 during which time he has engaged in research activity. Mr. Charlton served on the therapeutics committee during 1946–47.

Estill I. Green (A '23, M '30, F '46) assistant director of transmission development, Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed 1947–48 chairman of the AIEE instruments and measurements committee. Born in St. Louis, Mo., on November 24, 1895, Mr. Green was graduated from Westminster College in 1915 with a bachelor of arts degree. He did graduate work at the University of Chicago from 1915 to 1916, and in 1921 received a bachelor of science degree in electrical engineering and business administration from Harvard University. Mr. Green became affiliated with the American Telephone and Telegraph Company, New York, N. Y., in 1921, being engaged in development and

research work until 1934 when he transferred to the transmission development department. He has received many patents for his inventions, and is the author of several papers which have been published in various technical magazines. He is a member of the Institute of Radio Engineers, and has served on the AIEE instruments and measurements committee since 1942.

J. E. McCormack

E. E. Charlton



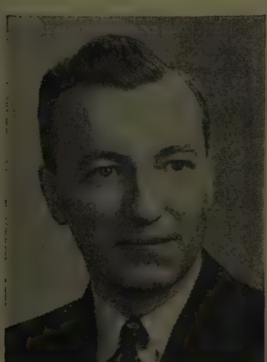
C. H. Willis

Clodius Harris Willis (A '22, M '28, F '42) professor of electrical engineering, Princeton (N. J.) University, has been appointed chairman of the AIEE electronics committee for 1947–48. Born on August 5, 1893, in Lignum, Va., Doctor Willis received a bachelor of science degree from the University of Richmond in 1914, and an engineering degree from Johns Hopkins University in 1916. After completing a cadet course with the New York Edison Company in 1917, and serving with the Army of the United States until 1919, Doctor Willis was an acting professor of physics at the University of Richmond, Va., from 1919 to 1920. He was made an associate professor of physics there in 1920, but left in 1922 to do graduate work at Johns Hopkins University. In 1920 Doctor Willis returned to the University of Richmond as professor of applied physics, leaving in 1925 to return to Johns Hopkins to work on his doctor of philosophy degree which he obtained in 1926. He became affiliated with Princeton University in 1926 as an assistant professor of electrical engineering, and advanced to his present position in 1937. Doctor Willis is a member of the American Physicists Society, the Institute of Radio Engineers, Sigma Xi, Phi Beta Kappa, and Tau Beta Pi. He served on the AIEE Standards committee (1942–1946), and has been on the electronics committee since 1943. He was vice-chairman of the latter committee, for 1946–47.

John Charles Aydelott (M '32) transportation motor engineering department, General Electric Company, Erie, Pa., has been appointed 1947–48 chairman of the AIEE land transportation committee. Born on March 19, 1898, in Pekin, Ill., he was graduated in 1920 from Rutgers University with a bachelor of science degree. In 1920 Mr. Aydelott became associated with the General Electric Company in the testing department, transferring to the transportation motor engineering department in 1922. He has been a member of the AIEE land transportation committee since 1941.

Harris Reinhardt (M '42) Sylvania Electric Products, Inc., Salem, Mass., has been appointed chairman of the AIEE production and application of light committee for 1947–48. Born on November 13, 1909, in Des Arc, Ark., Mr. Reinhardt was graduated from the University of Arkansas with a bachelor of science degree in electrical engineering in 1931. He received his master of science degree from Ohio State University in 1935, during which time he also was a graduate assistant in electrical engineering. In 1935 Mr. Reinhardt accepted a position as illuminating engineer with Westinghouse Lamp Division, Bloomfield, N. J., transferring to a similar position with the Hygrade Sylvania Corporation, Danvers, Mass., in 1940. The new chairman is a member of the Illuminating Engineering Society, and has been on the AIEE production and application of light committee since 1942.

Samuel Dewey Summers (A '37, M '46) staff consultant, aircraft electrical research division, Naval Research Laboratory, Washington, D. C., has been appointed chairman of the AIEE air transportation committee for 1947–48. Born on July 5, 1898, at Hornbeak, Tenn., Mr. Summers was graduated from Tri State College, Angola, Ind., in 1923 with a bachelor of science degree in electrical engineering, and then taught physics and electricity there until 1924. He later attended the Massachusetts Institute of Technology and the University of Michigan for graduate work. Afterwards Mr. Summers was a teacher in the Tri State College's school of electrical engineering until 1943 when he entered the United States Navy. He retired to inactive duty in 1945, and subsequently became affiliated with the Naval Research Laboratory at Washington, D. C. Mr. Summers served as vice-chairman of the Fort Wayne (Ind.) Section of the AIEE in 1941–42 and as chairman of that Section in 1942–43. He was also on the AIEE air transportation committee for 1946–47.



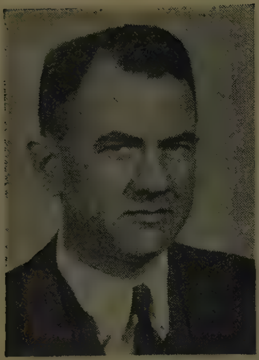
W. R. Brownlee

E. H. Vedder

J. L. Callahan

Julius C. Strasbourger (A '31, M '40) supervising engineer, electrical department, Cleveland (Ohio) Electric Illuminating Company, has been appointed 1947–48 chairman of the AIEE Sections committee. Born in Cleveland, Ohio, on December 22, 1906, Mr. Strasbourger was graduated from the University of Cincinnati with an electrical engineering degree in 1929. He received a bachelor of laws degree from the Cleveland Law School in 1934, and took electrical courses at the Case School of Applied Science in 1938. He became affiliated with the Cleveland Electric Illuminating Company is 1929 as an assistant electrical engineer in the electrical engineering department. Mr. Strasbourger served as secretary of the Cleveland Section from 1939 to 1942, and he served as chairman of that Section for the year 1946–47.

E. R. Thomas (A '25, M '30) test engineer, the Consolidated Edison Company of New York (N. Y.) Inc., was made an honorary officer of the Order of the British Empire recently. The presentation of the insignia and citation was made by Sir Francis Evans, British Consul General. The citation stated that Colonel Thomas "has played a major part in radar planning and development with particular reference to ground equipment and controlled landing equipment—his grasp of operational prob-



J. C. Aydelott

Harris Reinhardt

S. D. Summers

B. D. Hull

lems and enthusiastic collaboration have contributed notably toward the mutual efficiency of the British and American air forces in this sphere of the war effort." During the war, Colonel Thomas directed research and development of electronics for the United States Army Air Forces and maintained liaison in this field with the Royal Air Force. He was in uniform from 1942 to late 1945. He was a 1922 graduate of the Massachusetts Institute of Technology, when he received a bachelor of science degree in electrical engineering.

Vannevar Bush (A '15, F '24) president, Carnegie Institution of Washington (D. C.), and former chairman of the wartime Office of Scientific Research and Development, has been appointed chairman of the Research and Development Board by President Truman. In his new post he will co-ordinate all military research of the three service arms of the new unified defense command. Doctor Bush was born in Everett, Mass., March 11, 1890, and was graduated from Tufts College with the degrees of bachelor and master of science in 1913. He has received honorary doctorates from that institution and from nine other leading colleges and universities. He has received the Levy Medal of the Franklin Institute (1928), the AIEE Lamme Medal (1935), the Holley Medal of the American Society of Mechanical Engineers, the John Scott Medal of the Philadelphia City Trustees (1943), the AIEE Edison Medal (1943), the Washington Award (1946), and the Hoover Medal (1946). Doctor Bush served on governmental committees under the late President Roosevelt, and has been extremely active in other organizational work. He has served on the AIEE committees on electrophysics, 1924–33, chairman, 1931–33; power transmission and distribution, 1925–29; research, 1924–30 and 1939–41; education, 1928–29; Edison Medal, 1933–48; Lamme Medal, 1936–39, chairman 1938–39; co-ordination of Institute activities, 1937–38; and was the AIEE representative on the National Research Council, Division of Engineering and Industrial Research, 1935–39; and on the American Association for the Advancement of Science council, 1938–40. He was also a director of the Institute from 1937 to 1941.

B. D. Hull (A '15, F '39) AIEE president for 1947–8, has retired from the position of chief engineer, Southwestern Bell Telephone Company, St. Louis, Mo. Born on September 12, 1882, in Galesburg, Mich., he was graduated from the University of Kansas in 1905. After graduation he was associated with the Missouri and Kansas Telephone Company, Kansas City, Mo., and in 1912, when that company was absorbed by the newly formed Southwestern Bell Telephone Company, he was transferred to St. Louis in the capacity of general transmission and protection engineer for the entire area of the new company. He was appointed chief engineer for the company in 1936. Mr. Hull was chairman of the St. Louis Section of the AIEE for 1925–26, and served as a director of the Institute from 1931 to 1935. He was vice-president for the South West District from 1928 to 1930. He has served on numerous AIEE committees, and in 1944 was general chairman of the summer meeting committee. He is also a member of the Engineers, Club of St. Louis.

H. E. Ives (F '29) electro-optical research director, Bell Telephone Laboratories, Inc., New York, N. Y., has retired. Doctor Ives holds the degrees of bachelor of science from the University of Pennsylvania (1905), and doctor of philosophy from Johns Hopkins University (1908). He began his career as physicist with the Bureau of Standards, Washington, D. C., and in 1909 was appointed physicist in the National Electric Lamp Association, Cleveland, Ohio. He was physicist for the United Gas Improvement Company, Philadelphia, Pa., from 1912 to 1918. After serving in the United States Air Service during the first World War, he joined the technical staff of Bell Telephone Laboratories. Doctor Ives was in charge of the general development of picture transmission over telephone lines which was used first at the national political convention in 1924, and also had charge of the investigation of television which resulted in the first demonstration from Washington to New York in 1927. More recently his experimental verification of the change in rate of a moving atomic clock by spectroscopic observation of high-speed hydrogen canal rays furnished the first direct proof of the system of compensation for motion embodied in the theories of Larmor, Lorentz, and Einstein. During World War II he worked with the National Defense Research Committee. He is the author of many scientific and technical papers and has received three Longstreth Medals from the Franklin Institute for work in color photography, "artificial" daylight, and studies of the Welsbach mantle; the John Scott Medal, awarded annually by the City of Philadelphia for contributions to telephotography and television; and the Frederic Ives Medal of the Optical Society of America for distinguished work in optics. The honorary degree of doctor of science was conferred on him by Dartmouth College and Yale University in 1928, and by the University of Pennsylvania in 1929. Doctor Ives is a past president of the Optical Society of America, a past vice-president of the Illuminating Engineering Society, and a

J. C. Strasbourger

E. R. Thomas

Vannevar Bush

member of the National Academy of Science, the American Association for the Advancement of Science, the American Philosophical Society, the American Physical Society, the Franklin Institute, Phi Beta Kappa and Sigma Xi.

L. R. Crane (A '41) formerly switchgear application engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed Chicago, Ill., district manager for the A. B. Chance Company, Centralia, Mo. Mr. Crane holds the degrees of bachelor of science and master of science in electrical engineering from North Carolina State College.

D. B. Perry (A '21, M '28) engineer in the department of operation and engineering, American Telephone and Telegraph Company, New York, N. Y., recently was elected a trustee of the American University of Beirut, Lebanon.

C. L. Davis (A '29, M '37) patent attorney of Washington, D. C., has transferred his law practice to Perry, Mo. Mr. Davis was in charge of the Washington office of the patent department of the Radio Corporation of America for 15 years. He is a past chairman of the Washington section of the Institute of Radio Engineers and a past chairman of the committee on legislation for the patent section of the American Bar Association.

F. E. Hanson (M '39) who has been in charge of engineering at the electronics shop of the Western Electric Company, in New York, N. Y., and Allentown, Pa., has been appointed manager of the shop. Mr. Hanson joined the company in Chicago in 1918 as a process material inspector. In 1929 he was transferred to the Kearny, N. J., plant to do manufacturing engineering work. He joined the New York headquarters during the war becoming superintendent of manufacturing engineering in 1943 and taking charge of manufacturing operations in the electronic shops in 1945. In 1946 Mr. Hanson was one of four engineers honored by the American Standards Association for distinctive war service.

David Sarnoff (M '23) president, Radio Corporation of America, New York, N. Y., also has been appointed chairman of the board of the corporation.

Francis Hodgkinson (A '02) consulting mechanical engineer, New York, N. Y., has been appointed an honorary member of the American Society of Mechanical Engineers.

Chester Russell, Jr. (A '29, M '34) professor of electrical engineering, Michigan College of Mining and Technology, Houghton, has been appointed resident director of the college's Sault Sainte Marie branch. Professor Russell holds the bachelor of science (1926) and master of arts (1933) degrees from the University of Mexico and a master of science degree (1940) from the University of Michigan. Professor Russell taught in the University of New Mexico, Albuquerque, N. Mex., from 1929 to 1939 and was head of the department of electrical engineering from 1937 to 1939. He became head of the department of electrical engineering at the University of Denver (Colo.) in 1939, and joined the faculty of Michigan College in 1941 as associate professor of electrical engineering and acting head of the department.

C. W. LaPierre (M '45) formerly manager of the mechanical division, General Electric Company, N. Y., has been appointed vice-president in charge of engineering for American Machine and Foundry Company. Mr. LaPierre, who attended the University of Missouri, entered the test department of the General Electric Company in 1924. Before becoming manager of the electrochemical division, he was in charge of the development section of the general engineering laboratory. In 1937 he received the company's Charles A. Coffin award for outstanding accomplishments. He is a past chairman of the AIEE Schenectady Section.

G. H. Davis (A '33) formerly division engineer, Connecticut Light and Power Company, Tomkinville, has been appointed western division manager for the company. Mr. Davis joined the company in 1927.

R. A. Heising (A '15, F '39) crystal research engineer, Bell Telephone Laboratories, Inc., New York, N. Y., recently was awarded the honorary degree of doctor of science by the University of North Dakota.

D. E. Branson (A '21) telegraph engineer, **R. H. Clapp** (A '20, M '26) of the transmission engineering department, and **Harry Nyquist** (M '24) associate engineer, recently completed 30 years with Bell Telephone Laboratories, Inc., New York, N. Y. **F. B. Blake** (M '36) member of the technical staff, **V. T. Callahan** (A '23), **J. M. Duguid** (M '44) member of the technical staff, **R. A. Leconte** (A '23, M '30) member of the technical staff, and **W. K. St. Clair** (A '22, M '28) have been with the laboratories for 25 years.

R. C. Davis (M '41) member of the technical staff, Bell Telephone Laboratories, Inc., New York, N. Y., has been made switching development engineer.

F. M. Gunby (A '10, M '14) director, Charles T. Main, Inc., Boston, Mass., has been nominated as regional vice-president of the American Society of Mechanical Engineers.

A. L. Penniman, Jr. (A '15, F '43) general superintendent, electric operations department, Consolidated Gas Electric Light and Power Company of Baltimore (Md.) has been nominated a director at large of the American Society of Mechanical Engineers.

Sir Leonard Pearce (A '08, F '12) engineer in chief, London (England) Power Company, Ltd., has been elected an honorary member of the Institution of Mechanical Engineers.

R. A. Haislip (A '21, M '21) director, outside part developments, Bell Telephone Laboratories, Inc., Murray Hill, N. J., has completed 40 years of service with the Bell system. **T. C. Campbell** (A '19, M '26) engineer, equipment development department, Bell Laboratories, New York, N. Y., has been with the laboratories for 30 years. **J. R. P. Goller**, member of the technical staff, assistant development department, and **F. J. Singer** (A '36, M '38) telegraph development engineer, assistant development department, have completed 25 years with the corporation.

Uriah Davis (A '25, M '26) chief load dispatcher of Commonwealth Edison Company, Chicago, Ill., is retiring after 43 years of service, having been in the electrical industry since 1900. He entered the employ of the Edison Company in 1904 as an apprentice substation operator. In 1906 Mr. Davis transferred to the load dispatcher's office, and 18 years later was appointed assistant chief load dispatcher. He was advanced to the position of chief load dispatcher in 1943.

W. D. Kyle, Jr. (A '37, M '44) president of the Kyle Corporation, South Milwaukee, Wis., has been appointed vice-president of the Line Material Company, Milwaukee, Wis. For the present, he will retain both positions.

James DeKiep (M '43) chief engineer, Electric Machinery Manufacturing Company, Minneapolis, Minn., has been named to the board of directors of that company. **C. C. Nelson** (M '36) works manager of the same company, also was elected to the board.

H. J. Stewart (A '38) formerly assistant to the manager of the General Electric Company in York, Pa., has been appointed manager of the company's Marginal Street Works in Lowell, Mass. Mr. Stewart has been with the General Electric Company since 1926.

J. G. Hughes (A '39) formerly a captain in the Army of the United States, serving in the office of the Chief of Chemical Warfare Service, has been appointed district manager for electric appliance sales, The Yale and Towne Manufacturing Company, New York, N. Y. The district assigned to him includes upstate New York and Connecticut.

T. H. Hogg (M '31, F '38) formerly chairman of the Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been named to head the Manitoba (Canada) Water Power Commission. (*For full biography of Doctor Hogg see EE, May '47, p 503.*)

E. H. Will (M '46) formerly president of the El Paso Electric Company, El Paso, Tex., has been appointed general manager of operations of The Virginia Electric and Power Company at Richmond.

T. O. Sweatt (M '44) and **E. L. Carlson** (A '26) formerly of Burns and Roe, New York, N. Y., and **G. E. Wearn** (A '46) formerly with the Westinghouse International Corporation, New York, have announced the formation of Wearn, Vreeland, Carlson, and Sweatt, a consulting engineering firm in New York specializing in the design and construction of power generation, transmission, and distribution facilities.

H. S. Patton (A '22) previously manager of industrial relations for the Public Service Company of Northern Illinois, has been elected a vice-president of that company.

Christian Winther (A '43) regional supervisor for the Westinghouse International Company, located in Oslo, Norway, has been awarded the Order of St. Olav First Class by King Haakon of Norway.

B. W. Kendall (M '18, F '29) research consultant at Bell Telephone Laboratories Inc., New York, N. Y., was elected second vice-president of the New York Electrical Society for the 1947–48 term.

Cecil Dannatt (A '29) deputy chief electrical engineer since 1945 at Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, England, has been appointed chief electrical engineer of that company.

L. B. Hutton (A '23, M '31) general manager of the Wellington (New Zealand) Electricity and Tramways Department, is president of the New Zealand Institution of Engineers for 1947.

H. T. Rappel (A '45) previously student engineer with the Canadian General Electric Company, Ltd., Peterboro, Ontario, has been appointed general application engineer in the Edmonton, Alberta, Canada, office.

Morton Sultzer (A '13, M '34) affiliated with the Bell Telephone Laboratories, Inc., New York, N. Y., has been appointed personnel planning director for that organization.

J. N. Ewart (A '31, M '34) superintendent of production, Buffalo (N. Y.) Niagara Electric Corporation, has been appointed chief mechanical engineer. Mr. Ewart joined the company in 1929 as assistant field engineer. In 1939 he became superintendent of the Huntley Stations and in 1945 was named superintendent of production for the company.

M. E. Skinner (M '46) director of sales, Union Electric Company, St. Louis, Mo., recently was elected to the board of directors of the Missouri State Chamber of Commerce.

F. L. Roe (A '19, M '28) formerly power superintendent, Salt River Valley Water Users Association, Phoenix, Ariz., has been appointed chief engineer.

J. V. B. Duer (A '15, F '29) assistant to vice-president-operation, Pennsylvania Railroad Company, Philadelphia, Pa., has retired. Mr. Duer holds the degree of mechanical engineer from Stevens Institute. He joined the Pennsylvania System in 1905 as electrical inspector for the Long Island Railroad. He subsequently held the positions of foreman of motormen, assistant electrical engineer, electrical engineer, and in 1935 was appointed chief electrical engineer. He was made assistant to the vice-president in 1941. Mr. Duer was prominently concerned with the electrification of the railroad's Eastern seaboard line.

R. M. Prendergast (M '44) formerly manager, apparatus division, Canadian General Electric Company, Ottawa, Ontario, has been appointed application engineer in the company's industries and application section.

W. G. B. Euler (A '08, M '33) formerly vice-president in charge of operations, Pacific Gas and Electric Company, San Francisco, Calif., has been appointed vice-president and general manager. A graduate of the University of California, Mr. Euler was general superintendent of the Great Western Power Company when it merged with the Pacific Company in 1910. He became chief engineer of the Pacific Company in 1940 and vice-president in charge of operations in 1944. **D. D. Smalley** (A '20, M '33) engineer of electric operation, has been appointed a vice-president of the company. Mr. Smalley has been with the company since his graduation from the University of California in 1910. He was general superintendent of the San Joaquin and Midland Counties properties of the company at the time of his appointment as engineer of electric operation in 1946. **J. S. Moulton** (A '22, M '27) executive engineer, also has been appointed a vice-president. He joined the company in 1921, the year he was graduated from Yale University. He has held the positions of executive engineer of the Great Western Power Company and assistant to the vice-president and general manager.

E. C. Metcalf (A '31, M '45) formerly operations engineer for R. W. Beck and Associates, Seattle, Wash., has started his own practice as electrical and mechanical consulting engineer, Wenatchee, Wash. A graduate of Bucknell University, Mr. Metcalf has been associated with the General Electric Company, Schenectady, N. Y.; the New York (N. Y.) Board of Transportation; the Hartford Steam Boiler Inspection and Insurance Company, Philadelphia, Pa.; and the Fidelity and Casualty Company, New York.

R. W. Tassie (A '12, M '18) engineer with Ebasco International Corporation, New York, N. Y., has been appointed operating sponsor for Mexico by the company. A specialist in the Latin American electric light and power industry, Mr. Tassie has supervised operations in Cuba, Venezuela, Brazil, and Guatamela.

R. S. Wallace (A '44) chairman of the board, Central Illinois Light Company, Peoria, Ill., has been honored by the company which has renamed its East Peoria station, the R. S. Wallace Station.

H. P. Liversidge (A '12, F '33) formerly president, Philadelphia Electric Company, has been named chairman of the board of the company. **H. B. Bryans** (F '18) formerly executive vice-president, has been elected president, and **N. E. Funk** (A '07, F '34) formerly vice-president in charge of engineering, has been made executive vice-president and a member of the board of directors.

R. P. Brown (A '10, M '13) chairman of the board, Brown Instrument Company, Philadelphia, Pa., has been awarded the honorary degree of doctor of engineering by Drexel Institute.

G. W. Spaulding (A '24, M '32) formerly vice-president, Pennsylvania Water and Power Company, Baltimore, Md., has been appointed executive vice-president of the company, and **Donald Gunn** (M '36) chief engineer of the company, has been elected a vice-president.

Frank Walsh (A '26, M '30) division manager, Puget Sound Power and Light Company, Seattle, Wash., has been transferred to Olympia, Wash., as manager of the company's southern division.

A. M. Chitty (M '22) manager, Southern division, Puget Sound Power and Light Company, Olympia, Wash., has retired. Mr. Chitty has been with the company since 1902.

F. L. McKee (A '40) formerly with the Philadelphia (Pa.) Electric Company, has joined the Eastern Shore Public Service Company as division engineer at Harrington, Del.

G. H. Hager (A '20, M '36) formerly assistant engineer, operating department, Pacific Gas and Electric Company, San Francisco, Calif., has been appointed engineer of electric operations. Mr. Hager, a graduate of the University of California, has been associated with the Pacific Company and its predecessors for 35 years. He was appointed assistant engineer of operations in 1930. **H. G. Keesling** (A '19) formerly division superintendent, East

Bay division of the company, has been appointed central area superintendent.

H. V. Rathbun (A '29, M '37) has been appointed transmission and distribution engineer for the Western Light and Telephone Company, Kansas City, Kans. Mr. Rathbun most recently was associated with the Copperweld Steel Company, Glassport, Pa.

H. A. Frey (A '28, M '43) formerly research and development engineer, Locke Insulator Corporation, Baltimore, Md., has been appointed chief development engineer for the company. A graduate of Johns Hopkins University, Mr. Frey has been associated with the company since 1926. He was chairman of the AIEE Maryland Section for 1939–40 and has served on a number of AIEE committees.

H. H. Ganser (M '18) regional vice-president, Philadelphia Electric Company, Norristown, Pa., has retired. Mr. Ganser has been associated with the company since 1899. He is a past president of the Pennsylvania Electric Association and the Pennsylvania Gas Association and has been active in his state and local chambers of commerce.

OBITUARY ••••

Walter Guy Rubel (A '18, M '28) transmission and protection engineer, Mountain States Telephone and Telegraph Company, Denver, Colo., died July 24, 1947. Born on May 13, 1885, in Kirkville, Iowa, Mr. Rubel was graduated from Iowa State College with a bachelor of science degree in electrical engineering in 1906, and a bachelor of science degree in mechanical engineering in 1907. He was employed by companies in Washington and California, and became affiliated with the Mountain States Telephone and Telegraph Company in Denver, Colo., in 1915, as an assistant appraisal engineer. Mr. Rubel was a member of the Colorado Engineering Council and the Colorado Society of Engineers. He was secretary of the North Central District (6) from 1933 to 1935, served on several national committees, and was chairman of the Denver Section for the year 1940–41.

Henry Parmenter Berry (A '26, M '32) engineer, Chesapeake and Potomac Telephone Company of West Virginia, Charleston, died on April 22, 1947. He was born on December 26, 1900, in Washington, D. C., and after receiving a bachelor of science degree in electrical engineering from Catholic University in 1924, entered the employ of the Chesapeake and Potomac Telephone Company in Washington, D. C., as a student engineer. He later was promoted to engineering assistant in equipment engineering, and in 1929 was transferred to the company's branch office located in Charleston, W. Va. Mr. Berry belonged to the Institute of Radio Engineers.

William Harry Collins (M '46) electrical engineer, Lansing Board of Water and Electric Light Commissioners, Lansing, Mich., died on June 3, 1947. Born in Lincoln County, S. Dak., on April 24, 1889, he was graduated in 1918 from the University of Michigan with a bachelor of science degree in electrical engineering. He was affiliated with the Utah Power and Light Company in Salt Lake City until 1921 when he was employed by the Central Arizona Light and Power Company as superintendent of construction. In 1927 Mr. Collins became associated with the Lansing Board of Water and Electric Light Commissioners with whom he remained until his death.

Henry A. Germain (A '25) commercial engineer, The General Electric Company, Pittsfield, Mass., died recently. Born on October 3, 1881, in the province of Ontario, Canada, he received a bachelor of science degree from Queen's University in 1907. After graduation he was employed by the General Electric Company in Pittsfield, Mass., at first in testing and shop work, and then in designing special and power transformers, and the like.

Louis N. Persio (A '34) chief engineer, Radio Station *WRAK* Inc., Williamsport, Pa., died on August 6, 1947. Born on February 29, 1908, in Erie, Pa., he received his technical training at the Chicago Institute of Radio in commercial radio engineering. While a student he was employed by the Keystone Radio Laboratories, Chicago, Ill., as a laboratory assistant. In 1928 Mr. Persio became affiliated with the radio station *WRAK* in Erie, Pa., and in 1930 he transferred to Williamsport's *WRAK* station as an engineer. He was made chief engineer in 1934 and held that position until his death. He was a member of the International Radio Engineers and president of the Williamsport chapter of that organization.

Carleton Eli Torrey (A '05) retired, vice-president and general manager of the Ohio Power Company, Canton, died on August 15, 1947. Born on April 26, 1879, at Lorraine, N. Y., he received his technical education at Armour Institute. Mr. Torrey was employed by a water and light company in Sault Sainte Marie, Ontario, and the Janesville (Wis.) Electric Company, before coming to Canton as assistant manager for the Canton Electric Company at the time this company became part of the Ohio Power Company. In 1917 he became manager of the East Liverpool (Ohio) division, and in 1920 he was transferred to Atlantic City, N. J., as general manager of the Atlantic City Electric Company. He returned to Canton in 1923 as general manager for the Ohio Power Company, and in 1930 was elected vice-president of that firm. Mr. Torrey was a director of the Ohio Chamber of Commerce and of the American Gas and Service Corporation.

James Garfield Heath (A '37) plant foreman and engineer, municipal electricity department, Timaru (New Zealand) Borough Council, died suddenly on April 6, 1947. Born on April 10, 1899, in Dunedin, New Zealand, he received his technical education at Canterbury College. From 1916 to 1921 he served an apprenticeship with the firm of Turnbull and Jones, Dunedin, and in 1921 he became associated with the Otagoo Harbour Board as an assistant engineer. In 1922 he was employed as a foreman for the National Electrical Company, and in 1923 he was appointed engineer in charge of the Motueka (New Zealand) Borough Council. Mr. Heath then was associated with the Wilson Portland Cement Company, Ltd., Whangarei, New Zealand, and the firm of Vickerman and Lancaster, before coming to Timaru. There, as plant engineer for the Timaru Borough Council, all of the equipment and plant were under his supervision.

Henry Harold Higbie (A '08, M '12, F '43) professor of electrical engineering, University of Michigan, Ann Arbor, died on August 3, 1947. Born in 1882, November 10, in New York, N. Y., he was graduated from Columbia University in 1904 with a bachelor of science degree in electrical engineering. From 1904 to 1905 Mr. Higbie was an assistant in mechanical engineering attached to the experimental mechanical engineering laboratory at Columbia University, New York, N. Y. In 1905 he taught mechanical engineering at the University of Michigan, and in 1907 was an instructor in electrical engineering at that school. He was advanced to the position of assistant professor of electrical engineering in 1909, and left in 1911 to head the departments of electrical construction and operation, and also the power plant practice, at the Wentworth Institute, Boston, Mass. He returned to the University of Michigan in 1913 as professor of electrical engineering, remaining there until his death. Mr. Higbie was a member and officer in Tau Beta Phi, Theta Xi, and Sigma Xi; a member of the Optical Society of America; American Association of University Professors; Society for Promotion of Engineering Education; and a member and past president of the Illuminating Engineering Society. He was chairman of the AIEE Detroit–Ann Arbor Section for the year 1917–18.

Mark Rittenhouse Woodward (A '11, M '18) director, cement plants division, Vulcan Iron Works, Wilkes-Barre, Pa., died recently. Born in Washington, D. C., on March 20, 1883, he was gradu-

ated from George Washington University in 1905 with an electrical engineering degree. From 1906 to 1907 he was employed by the Potomac Electric Power Company, Washington, D. C., as an inspector, and in 1907 he was associated with the Navy Department in electrical aid, Bureau of Yards and Docks. At the same time Mr. Woodward was an instructor in electrical engineering at the National Correspondence Institute in Washington, D. C., and in 1910 he began teaching electrical engineering at George Washington University, Washington, D. C. Before he was associated with Vulcan Iron Works, Mr. Woodward was employed by the Marblehead Lime Company, Chicago, Ill., in the capacity of chief engineer. He was a past president of the Engineers' Club of the Lehigh Valley, and a member of the general power application committee of the AIEE.

Joseph Walker Cowles (A '02, M' 03) retired, formerly superintendent of the installations department, Boston (Mass.) Edison Company, died recently. Born on April 18, 1869, at Norfolk, Conn., he was graduated from Cornell University in 1890 with an electrical engineering degree. After graduation he was employed for three years by the General Electric Company in Lynn and Boston, Mass. In 1895 he joined the Boston Electric Light Company, and when, in 1901, the Boston Edison Company purchased the former concern, Mr. Cowles became associated with the laboratory staff. He became head of the installations department a year later, and retired on May 1, 1935, after 40 years of service with that company. He was a former member of Delta Upsilon fraternity, the Boston Engineers' Club, and of the Masonic Order.

George Lowthane Greves (A '15, M '25) engineer, Pacific Telegraph and Telephone Company, San Francisco, Calif., died on September 6, 1947. Born in Angus, Iowa, on December 6, 1885, he attended Bradley Polytechnic Institute in 1904–07 and 1909–10, taking a general science and engineering course. He was enrolled at the University of Illinois from 1911 to 1913 when he received a bachelor of science degree in electrical engineering. In 1913 Mr. Greves was appointed an instructor of electrical engineering at the Case School of Applied Science (now the Case Institute of Technology) Cleveland, Ohio. He accepted a position as instructor of electrical engineering at the University of California, Berkeley, in 1916, after he had received a master of science degree in electrical engineering from that school. In 1919 he was advanced to assistant professor of electrical engineering, a position which he held until 1927 when he became affiliated with the Pacific Telegraph and Telephone Company. Mr. Greves was a member of the AIEE basic sciences committee for the year 1946–47.

Frederick Jacob Murmann (A '07, M '13) retired superintendent of substation operation, Westchester Lighting Company, Mount Vernon, N. Y., died recently. Born on November 3, 1873, at Pawling, N. Y., Mr. Murmann became associated with the Eastchester Electric Company as a wireman in 1895, and when the company was absorbed by consolidation with the Westchester Lighting Company, he affiliated himself with that organization. In 1897 he was promoted to a meterman and in 1901 was made foreman of the meter department. He became superintendent of the meter department in 1906, and in 1910 was appointed superintendent of electric meters and substations. He retired in 1940 after completing more than 45 years of service with the Westchester Company.

Ladislas Peter Graner (A '23, M '27) consulting engineer, New York, N. Y., died on September 24, 1947. Born in Budapest, Hungary, on June 23, 1892, he attended the Institute of Technology in Budapest from 1910 to 1912, and the Institute of Technology, Karlsruhe, Germany, in 1912–1914 and in 1918, there receiving training in both mechanical and electrical engineering. He was employed as a research engineer in physical laboratories of the Philips Incandescent Lamp Factories, Eindhoven, Holland, from 1919 to 1923, when he came to the United States. Mr. Graner was employed by the Electric Specialties Company, Stamford, Conn., in the testing department in 1923, and in 1924 he became associated with the Sprague Safety Control and Signal Corporation, New York, N. Y., as an electrical and research engineer. He left that concern in 1928 to start his own business as a consulting engineer. Mr. Graner was president and director of L. P. Graner, Inc.; director and vice-chairman of Philips Laboratories, Inc.; director of North American Philips Company, Inc.; and director of Sprague Electric Company. He was a member of the Institute of Radio Engineers, New York Electrical Society, New York State Professional Engineers, Society of American Military Engineers, and the Illuminating Engineering Society.

James Calder Munro (M '45) manager of the general sales division, British Columbia Electric Railway Company, Ltd., Vancouver, died recently. Born on September 26, 1892, in Miami, Manitoba, British Columbia, he was graduated from the University of Manitoba in 1913 with a bachelor of science degree in electrical engineering. After more than four years service with the Canadian Army, Mr. Munro held the position of power sales engineer with the City of Winnipeg (Manitoba, Canada) Hydro-Electric System from 1919 to 1927. He then was employed as assistant manager in the light and power sales department, British Columbia Electric Railway Company, Ltd., Vancouver. In 1945 he was promoted to light and power sales manager, and in 1947 he assumed the position which he held at the time of his death.

Norman Hubert Coit (A '19, M '27, F '40) chairman of the board of the South Carolina Electric and Gas Company, Columbia, died on September 3, 1947. Born on December 9, 1894, in Indianapolis, Ind., he was graduated from the University of Colorado in 1917 with a bachelor of science degree in electrical engineering. From 1917 to 1918 he held the position of foreman in the switchboard installation department of the Mountain States Telephone and Telegraph Company, Denver, Colo., and in 1918 Mr. Coit was appointed superintendent of the Western Public Service Company, Auburn, Nebr. He became affiliated with the Pennsylvania Edison Company, Easton, in 1923, as assistant commercial manager. In 1924 he was associated with the Florida Public Service Company, Orlando, in the capacity of general manager and assistant to the vice-president. Mr. Coit accepted the position of vice-president and general manager of the South Carolina Electric and Gas Company and Lexington Water Power Company (later consolidated into the South Carolina Electric and Gas Company) in 1929, becoming president as well as general manager of that company in 1940. Mr. Coit served as secretary of the South Carolina Section of the AIEE from 1940 to 1942.

Richard Dorsey Sappington (A '19) superintendent of property maintenance and protection, Niagara Falls (N. Y.) Power Company, died recently. Born on April 19, 1892, in Frederick, Md., he was graduated from the University of Pennsylvania in 1915 with a bachelor of science degree in electrical engineering. In the following year he became affiliated with the Canadian Niagara Power Company, Niagara Falls, Ontario, as an inspector. Eight months later he was transferred to the power company's branch in Niagara Falls, N. Y., as an electrical assistant to the superintendent. In 1921 he returned to the Niagara Falls, Ontario, company as assistant superintendent. He was named assistant to the general superintendent of the power company in Niagara Falls, N. Y., in 1930, and later was promoted to the position which he held at the time of his death. Mr. Sappington was a member of Theta Chi fraternity.

Benjamin Rossiter Foote (A '19, M '45) research engineer, Hartford (Conn.) Electric Light Company, died recently. Born in Northford, Conn., on March 22, 1886, he later was graduated from Yale University in 1907 with a bachelor of philosophy degree. He became associated with the General Electric Company, Schenectady, N. Y., in 1907 and remained with that company until 1916 when he joined the staff of the Hartford Electric Company. Mr. Foote was employed in

the engineering department of that company until 1936 when he was promoted to the position which he held at the time of his death.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meetings of September 18, 1947, and October 2, 1947, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Bates, L. W., naval officer, power consultant, Bureau of Yards & Docks, Washington, D. C.
Bose, S. N., chief elec. engr., Tata Iron & Steel Co., Jamshedpur, India.
Bourland, L. T., consultant, radio engr., Naval Research Lab., Washington, D. C.
Carroll, J. S., prof. of elec. engg., Stanford Univ., Calif.
Lank, W. J., asst. to exec. vice pres., Potomac Electric Pr. Co., Washington, D. C.
Maryatt, E. F., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Roy, J. A. S., principal elec. engr., Bureau of Ordnance, Navy Dept., Washington, D. C.
Schultz, S. E., chief engr., Bonneville Pr. Adm., Portland, Oreg.
Smalley, D. D., vice pres. chge of operation, Pacific Gas & Elec. Co., San Francisco, Calif.
Thomson, J. M., genl. mgr., Ferranti Elec. Ltd., Toronto, Ontario, Canada.
White, E. L., chief, aviation div., engg. dept., Federal Communications Comm., Washington, D. C.

11 to grade of Fellow

To Grade of Member

Abbott, C. T., elec. engr., New England Gas & Elec. Assn., Cambridge, Mass.
Abbott, W. R., assoc, prof. of elec. engg., Iowa State College, Ames, Iowa.
Abramowitz, A., instructor in elec. engg., College of the City of N. Y., N. Y.
Albright, W., design engr., Westinghouse Elec. Corp., Sharon, Pa.
Anderson, L. D., physicist P-4, David Taylor Model Basin, Washington, D. C.
Barnett, H. E., supervising dist. maintenance foreman, Cinn. & Suburban Bell Tel. Co., Cincinnati, Ohio.
Basler, D. E., engineer, Rural Electrification Adm., Washington, D. C.
Berry, P. M. D., pres., Paul Berry, Inc., Oklahoma City, Okla.
Bollinger, W. H., elec. engr., The Esterline-Angus Co., Indianapolis, Ind.
Browne, A. A., genl. mgr., Pacific Elec. Mfgr. Corp., San Francisco, Calif.
Buchanan, G. E., mgr., application section, Delta Star Elec. Co., Chicago, Ill.
Cataldo, V. M., senior elec. engr., design div., Puerto Rico Water Resources Authority, San Juan, Puerto Rico.
Chafetz, A. B., design engr., International Min. & Chem. Corp., potash div., Carlsbad, N. Mex.
Chen, F. C. Y., chief engr., Chapei Electricity & Waterworks Co., Ltd., senior engr., Andersen Meyer & Co., Ltd., Shanghai, China.
Cragg, R. E., plant draftsman, Commonwealth Edison Co., Chicago, Ill.
Crane, G. J., works engr., Electric Reduction Co. of Canada, Ltd., Buckingham, Quebec, Canada.
Creager, P. S., assoc. prof. of elec. engg., Rutgers Univ., New Brunswick, N. J.
Creveling, A. B., Jr., elec. engr., American Car & Foundry Co., Berwick, Pa.
Day, C. R., elec. engr., Sacramento Municipal Utility District, Sacramento, Calif.
Derr, W. A., design engr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Duling, H. B., prof. of elec. engg., Georgia School of Tech., Atlanta, Ga.
Dunstan, L. A., elec. engr., Federal Power Comm., Washington, D. C.
Elbourn, R. D., elec. engr., U. S. Naval Ordnance Lab., Washington, D. C.
Ellis, W. G., commercial mgr., industrial electronics, RCA Victor Div., Camden, N. J.
Falk, M. C., research engr., Pittsburgh Plate Glass Co., Creighton, Pa.
Fell, W. J., member of firm of Cochrane, Fell & Wheeler, Tulsa, Okla.
Finison, H. J., application engr., General Elec. Co., Schenectady, N. Y.
Frank, R. L., project engr., Sperry Gyroscope Co., Great Neck, L. I., N. Y.
Garcia, I. M. A., senior engr., General Elec. Co., Hanford Engineer Works, Richland, Wash.
Gibbons, R. F., mgr., air brake div., Pacific Elec. Mgr. Corp., San Francisco, Calif.
Gibson, G. B., radio engr. (P-4) Naval Research Lab., Lab., Washington, D. C.
Gideon, W. I., asst. engr., Virginia Elec. & Pr. Co., Alexandria, Va.
Gilkeson, R. F., investigator of plant performance, Schuylkill Sta., Philadelphia Elec. Co., Phila., Pa.
Greene, D. L., elec. engr., Gilbert Associates, Inc., Reading, Pa.
Grondorf, H., elec. design engr., G. C. Moore & Co., San Francisco, Calif.
Hayward, F. W., elec. engr. (P-4) naval gun factory, Naval Ordnance Lab., Washington, D. C.
Higgins, C. F., elec. power dispatcher, National Advisory Comm. for Aeronautics, Cleveland, Ohio.
Hillery, R. H., asst. supt. of operation, Niagara Div., Hydro Elec. Pr. Comm. of Ontario, Toronto, Ontario, Canada.
Hird, F. S., dist. foreign wire relations supv., Northwestern Bell Tel. Co., Duluth, Minn.
Hoebel, H. F., distribution engr., American Gas & Elec. Serv. Corp., New York, N. Y.
Hopkins, C., electronics engr., Naval Research Lab., Washington, D. C.
Hulse, E. H., district engr., Westinghouse Elec. Corp., Los Angeles, Calif.
Jackson, C. H., radio engr. (Hq. AAF) Washington, D. C.
Jensen, I., asst. elec. engr., George G. Sharp, N. A., New York, N. Y.
Jones, R. W., genl. engg. dept. (distribution) Consumers Pr. Co., Jackson, Mich.
Jorow, E., engr., General Switch Corp., Brooklyn, N. Y.
Kaiser, F. D., design engr., Westinghouse Elec. Corp., Sharon, Pa.
Keep, O. A., asst. engr., trans. control div., General Elec. Co., Erie, Pa.
Kehoe, J. W., div. staff supvr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Keller, W. B., elec. engg., NACA/FPRL, Cleveland, Ohio.
Kelly, P. E., engr., Crouse-Hinds Co., Syracuse, N. Y.
Keneipp, H. E., elec. engr., Westinghouse Elec. Corp., Lima, Ohio.
Larard, F. J., senior elec. engr., Colonial Civil Service, Kuala Lipis, Malayan Union, Federated Malay States.
Logan, J. A., Youngstown representative, Allis-Chalmers Mfg. Co., Youngstown, Ohio.
Lueders, B. C., consulting engr., Baraboo, Wis.
Lyon, J. A. M., assoc. prof. of elec. engg., Northwestern Univ., Evanston, Ill.
Lythall, R. T., mgr., switchgear, transformer, & capacitor depts., Johnson & Phillips, Ltd., Charlton, London, England.
Madsen, L. D., application engr., General Elec. Co., Schenectady, N. Y.
Mancini, P. S., public service engr., City of Providence, Providence, R. I.
Manning, L. W., Jr., distribution engr., Mantahala Pr. & Lt. Co., Franklin, N. C.
Martin, W. G., III, motor engr., The Emerson Elec. Mfg. Co., St. Louis, Mo.
McClure, J. B., engr., power generation div., General Elec. Co., Schenectady, N. Y.
Merrell, E. J., supv. electrical research lab., Habirshaw Div., Phelps Dodge Copper Products Corp., Yonkers, N. Y.
Mezek, M. E., elec. engr., Commonwealth Edison Co., Chicago, Ill.
Mikolic, C. R., development engr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Miller, H. L., supt. meter & transformer depts., Houston Lighting & Pr. Co., Houston, Tex.
Moss, J. M., engr., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Nagy, A. W., research engr., Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.
Neblett, P. S., engr., design div., Texas Pr. & Lt. Co., Dallas, Tex.
Omin, W. W., electrical engr., public works dept., Philadelphia Naval Base, Phila., Pa.
Patton, F. A., telephone engr., Southeastern Tel. Co., Fitzerald, Ga.
Peterson, C. H., supervisor of methods-repair, New York Tel. Co., New York, N. Y.
Phillips, T. A., asst. supt. electrical dept., Central Arizona Lt. & Pr. Co., Phoenix, Ariz.
Pollyea, M. H., elec. engr., National Advisory Comm. for Aeronautics, Cleveland, Ohio.
Ports, D. C., consulting radio engineer, Washington, D. C.
Pratt, J. L., mgr. southwest region, Allis-Chalmers Mfg. Co., Dallas, Tex.
Reeser, E. S., Jr., control specialist and sales engr., General Electric Co., Pittsburgh, Pa.
Relis, M. J., elec. engr., naval gun factory, Naval Ordnance Lab., Washington, D. C.
Rivoire, O. G., professional elec. engr., Raymond L. Jenkins, Houston, Tex.
Robinson, A. W., Jr., field engr., Allis-Chalmers Mfg. Co., Miami, Fla.
Rugg, P. J., elec. engr., Tennessee Valley Authority, Knoxville, Tenn.
Rush, J. P., electrical supt., Taikoo Dockyard & Engg. Co., Ltd., Hong Kong, China.
Savage, J. W., district engr., Westinghouse Elec. Corp., Los Angeles, Calif.
Schreiber, M. A., engr., Applied Physics Lab., Johns Hopkins, Univ., Silver Spring, Md.
Sindeband, S. J., technical director, American Electro Metal Corp., Yonkers, N. Y.
Smith, C. C., elec. engr., naval gun factory, Naval Ordnance Lab., Washington, D. C.
Smith, D. B., vice-pres. in chge of engg., Philco Corp., Philadelphia, Pa.
Smith, P. D., plant mgr., Supreme Power Supplies Ltd., Mimico, Ontario, Canada.
Sullivan, A. H., Jr., radio engr.; asst. to chief, electronics section, TSNEL, Dayton, Ohio.
Tarpley, R. E., supervisory research technologist, Leeds & Northrup Co., Philadelphia, Pa.
Taylor, E., transmission line maint. supvr., Tennessee Valley Authority, Chattanooga, Tenn.
Tenzer, M., project engr., Continental Electronics Ltd., Brooklyn, N. Y.
Tolentino, J. G., elec. engr., Delco products div., General Motors Corp., Dayton, Ohio.
Townsend, M. A., member technical staff, Bell Tel. Labs., New York, N. Y.
Tuthill, H. E., district operating supt., N. Y. State Elec. & Gas Corp., Geneva, N. Y.
Tuttle, D. F., Jr., elec. engr. (student) Mass. Inst. of Technology, Cambridge, Mass.
Varhus, H. H., elec. engr., naval gun factory, Naval Ordnance Lab., Washington, D. C.
Wang, S. J., mgr. & engr., Shanghai Engg. Corp., Shanghai, China.
Wessely, G., asst. elec. engr., G. G. Sharp, N.A., New York, N. Y.
Whelpley, E. K., asst. elec. engr., Bureau of Light, Heat, & Power, City & County of San Francisco, Calif.
Ziemann, A. E., engr., G. E. X-Ray Corp., Chicago, Ill.

101 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candiates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before November 21, 1947, or January 21, 1948, if the applicant resides outside of the United States or Canada.

To Grade of Fellow

Deloraine, E. M., Intl. Tel. & Tel. Corp., New York, N. Y.
Petery, S. J., 198 Mt. Vernon Street, Dedham, Mass.

2 to grade of Fellow

To Grade of Member

Buchanan, W. A., (re-election) Burns & Roe, Inc., New York, N. Y.
Burford, G. G., North Wales Power Co., Ltd., Wrexham, Denbighshire, North Wales
Byrnes, I. F., Radiomarine Corp. of America, New York, N. Y.
Cahen, F. M., l'Electricite de France, Paris, France
Chapin, S. L., Public Service Elec. & Gas Co., Jersey City, N. J.
Cryer, K., Dept. of Trade & Commerce, Hamilton, Ontario, Canada
Durling, F. A., U. S. Embassy, Panama, Republic of Panama
Estcourt, V. F., Pacific Gas & Elec. Co., San Francisco, Calif.
Falk, H. H., American Cyanamid Co., Stamford, Conn.
Gallagher, J. T., Frigidaire Div., G. M. C., Dayton, Ohio
Gregory, A. H., Northern Elec. Co., Vancouver, British Columbia, Canada
Hancock, N. N., College of Technology, Manchester, England
Hermann, B. C., General Elec. Co., Pittsfield, Mass.
Hunter, T. M., Potomac Elec Power Co., Washington, D. C.
Kalbfell, D. C., Kalbfell Laboratories, Inc., San Diego, Calif.
Kimble, G. E., Illinois Power Co., Galesburg, Ill.
King, J. N., Westinghouse Elec. Corp., Allentown, Pa.
Kline, F. W., Long Island Lighting Co., Mineola, N. Y.
Laborde, M. E., l'Electricite de France, Paris, France.
Leeds, I. N., Ward Leonard Elec Co., Mt. Vernon, N. Y.
Lempert, J., Westinghouse Elec. Corp., West Caldwell, N. J.
Levy, L. M., Delco Products Div., G. M. C., Dayton, Ohio

Marsters, W. M., American Tel. & Tel. Co., New York, N. Y.
Mermel, T. W., Dept. of the Interior, Washington, D. C.
Naidu, S. R. M., Major, Military Engg. Service, Secunderabad, Deccan, India
Neal, J. P., Univ. of Illinois, Urbana, Ill.
Nicholls, E., RAF Station, Quedgeley, Gloucester, England
Nicholson, F. H., Union Switch & Signal Co., Swissvale, Pa.
Norris, F. E., General Tel Service Corp., New York, N. Y.
Pitman, A. C., Elec Specialty Co., Stamford, Conn.
Puchy, C. G., Jack & Heintz Precision Industries, Inc., Bedford, Ohio
Ross, D. L., Westinghouse Elec. Corp., Springfield, Mass.
Seaman, J. W., General Elec. Co., Philadelphia, Pa.
Sisco, Jr., S. E., Ebasco Services, Inc., New York, N. Y.
Smith, R. J., San Jose State College, San Jose, Calif.
Stout, G. P., Industrial Research Labs., Baltimore, Md.
Templeton, A. S., Midland Constructors Inc., Los Angeles, Calif.
Trent, R. L., Bell Tel. Labs., Inc., New York, N. Y.
van der Bliek, J., KLM Royal Dutch Airlines, Hollywood, Calif.
Young, R. A., Robert A. Young & Co., Los Angeles, Calif.
Wilson, A. G., Electronic Transmission Equipment Ltd., Brathway Works, London, England

41 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Andrade, A. R., Stromberg-Carlson Co., Rochester, N. Y.
Barnes, J. L., Intl. Business Machines, Endicott, N. Y.
Bleier, E. L., Stromberg-Carlson Co., Rochester, N. Y.
Brockmyre, H. C., Eastman Kodak Co., Rochester, N. Y.
Burnett, K. H., F. W. Sickles Co., Chicopee, Mass.
Canning, R. G., Intl. Business Machines Corp., Endicott, N. Y.
Carrel, R. E., Stromberg-Carlson Co., Rochester, N. Y.
Cochran, E. V., Stromberg-Carlson Co., Rochester N. Y.
Cunningham, R. H., Stromberg-Carlson Co., Rochester, N. Y.
Dietrich, C. J., Stromberg-Carlson Co., Rochester, N. Y.
Eckhardt, N. W., Stromberg-Carlson Co., Rochester, N. Y.
Frankel, T., Stromberg-Carlson Co., Rochester, N. Y.
Hagen, J. G., Stromberg-Carlson Co., Rochester, N. Y.
Hiers, C. W., General Elec. Co., Schenectady, N. Y.
Higgin, J. T., General Elec. Co., Pittsfield, Mass.
Hines, W. S., Westinghouse Elec. Corp., Buffalo, N. Y.
James, J. E., Eastman Kodak Co., Kodak Park, Rochester, N. Y
Jatras, S. J., Stromberg-Carlson Co., Rochester, N. Y.
Johnson, G. B., Stromberg-Carlson Co., Rochester, N. Y.
Jurgens, H. A., Intl. Business Machines, Endicott, N. Y.
Kenyon, A. O., New York State Elec. & Gas Corp. Binghamton, N. Y.
Lewis, L. S., General Elec. Co., Schenectady, N. Y.
Linden, E. E., The Narragansett Elec. Co , Providence, R. I.
McDade, T. J., General Elec. Co., Pittsfield, Mass.
Murch, D. E., Bethlehem Steel Co., Quincy, Mass.
O'Brien, J. E., Stromberg-Carlson Co., Rochester, N. Y.
Paige, A. E., Univ. of Rochester, Rochester, N. Y.
Puls, O. H. F., Stromberg-Carlson Co., Rochester, N. Y.
Reese, E. W., LeValley, McLeod Kincaid Co. Inc., Elmira, N. Y.
Remick, W. J., Simplex Wire & Cable Co., Cambridge, Mass.
Schultz, R. W., Stromberg-Carlson Co., Rochester, N. Y.
Sias, F. R., General Elec. Co., West Lynn, Mass.
Stauff, L. T., U. S. Rubber Co., Bristol, R. I.
Stowe, C. L., Stromberg-Carlson Co., Rochester, N. Y.

2. Middle Eastern

Ackermann, O., (re-election), Westinghouse Elec. Corp., East Pittsburgh, Pa.
Backus, W. J., Clark Controller Co., Cleveland, Ohio
Bennett, L. J., Ideal Elec. & Mfg. Co., Mansfield, Ohio
Besch, L. J., Westinghouse Elec. Corp., Sharon, Pa.
Black, Jr., A. O., Naval Ordnance Lab., Naval Gun Factory, Washington, D. C.
Cooke, D. A., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Fink, A. J., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hawes, J. G., Hawes Elec. Co., Huntington, W. Va.
Kettner, R. A., United Engineers & Constructors, Inc., Philadelphia, Pa.
Koo, K. T., Natl. Resources Comm. of China, c/o Westinghouse Elec. Corp., Pittsburgh, Pa.
Lipman, K., 5550 Raleigh St., Pittsburgh, Pa.
Louden, R. K., F. N. Cuthbert, Inc., Toledo, Ohio
McCollum, R. N., Westinghouse Elec. Corp., East Pittsburg, Pa.
McCourt, A. W., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Penkal, W. J., Jr., Victor R. Browning & Co., Willoughby, Ohio
Primm, A. E., Jr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Pulaski, M. E., Brush Development Co., Cleveland, Ohio
Schwab, R. L., Westinghouse Elec. Corp., Sharon, Pa.
Stone, L. R., Republic Steel Corp., Cleveland, Ohio
Stubenrauch, C. A., Philadelphia Elec. Co., Philadelphia, Pa.
Tarkenton, C. G., Delaware Pr. & Lt. Co., Wilmington, Del.
Thayer, J. N., Speed Control Corp., Wickliffe, Ohio
Thompson, J. E., Westinghouse Elec. Co., Sharon, Pa.
Triest, W. E., Natl. Bureau of Standards, Washington D. C.

3. New York City

Burns, S. S., Crocker Wheeler Mfg. Co., Ampere, N. J.
Dick, N. J., Jr., Long Island Lighting Co., Mineola, N. Y.
Drew, F. W., N. Y. Tel. Co., New York, N. Y.
Evans, F. S., General Elec. X-Ray Corp., New York, N. Y.
Fitzpatrick, F. R., Westinghouse Elec. Corp., Newark, N. J.
Foote, M. L., American Inst. of Elec. Engrs., New York, N. Y.
Ingersoll, V. L., Westinghouse Elec. Corp., New York, N. Y.
Janes, A. W., Gawler-Knoop, Inc., Newark, N. J.
Joseph, P. S., Richard A. Kent Co., New York, N. Y.
Keller, A. C. (re-election), Bell Tel. Labs., New York, N. Y.
Kelsey, R. M., Thomas A. Edison, Inc., Instrument Div., West Orange, N. J.
Liebrecht, E. C., Westinghouse Elec. Corp., New York, N. Y.
McKinney, E. B., Davis Transformer Co., Flushing, N. Y.
Ross, C. W., HQ Command, EUCOM, APO 757 c/o P. M., New York, N. Y.
Shahid, S. M., 99 Livingston St., Brooklyn, N. Y.
Sontheim R. F., Paulding, Inc., New York, N. Y.
Stateman, M. J., Microwave Research Inst., Brooklyn, N. Y.
Tick, D. J., Union College, Schenectady, N. Y.
Van Etten, W. D., N. Y. Tel. Co., New York, N. Y.

4. Southern

Anderson, J. W., Tennessee Valley Authority, Chattanooga, Tenn.
Barry, S. J., Barnard & Burk, Baton Rouge, La.
Burdeshaw, J. R., Tennessee Valley Authority, Chattanooga, Tenn.
Clancy, J. W., Birmingham Elec. Co., Birmingham, Ala.
Gregg, R. C., Tennessee Valley Authority, Chattanooga, Tenn.
Gullatt, S. P., Jr., Louisiana Polytechnic Inst., Ruston, La.
Paret, L. F., Westinghouse Elec. Corp., Norfolk, Va.
Sauber, J. W., Univ. of Tennessee, Knoxville, Tenn.
Wynne, W. G., Tennessee Valley Authority, Wilson Dam, Ala.

5. Great Lakes

Batzli, R. O., Batzli Elec. Co., Minneapolis, Minn.
Capps, J. H., General Elec. Co., Ft. Wayne, Ind.
Eakins, J. W., 423 Curtis Bldg., Detroit, Mich.
Elliott, D. D., North Indiana Public Service Co., Plymouth, Ind.
Epperly, C. S., Burgess-Norton Mfg. Co., Geneva, Ill.
Greenlee, T. K., Barber-Colman Co., Rockford, Ill.
Grothman, H. W., Northern Indiana Public Service Co., Hammond, Ind.
Hughes, M., Jr., Western Elec. Co., Chicago, Ill.
Kumm, H. B., Jr., General Elec. Co., South Bend, Ind.
Lukey, J. G., Public Service Co., Northbrook, Ill.
McCarthy, J. R., Intl. Harvester Co., Chicago, Ill.
Mueller, E. L., United Light & Railways Service Co., Davenport, Iowa.
Newman, A. F. (re-election), Ford Motor Co., Dearborn, Mich.
Rideout, V. C., Univ. of Wisconsin, Madison, Wis.
Seelhoff, M. R., Redmond Co., Inc., Owosso, Mich.
Simmons, T. E., Minnesota Pr. & Lt. Co., Duluth, Minn.
Stachel, E. F., American Coating Mills, Elkhart, Ind.
Swanson, W. A., Western Elec. Co., St. Paul, Minn.
Waidhas, G., (re-election), Harnischfeger Corp., Milwaukee, Wis.
Wattley, J. C., Allis-Chalmers Mfg. Co., Milwaukee, Wisc.
Youngvorst, L. H., Illinois Bell Tel. Co., Chicago, Ill.

6. North Central

McFall, E., U. S. Bureau of Reclamation, Denver, Colo.
Venkatesan, N., U. S. Bureau of Reclamation, Denver, Colo.

7. South West

Barker, J. L., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Benavides, O. C., (re-election), 917 Meadow, Laredo, Tex.
Clark, L. E., Southwestern Gas & Elec. Co., Marshall, Tex.
Geer, A. L., Shell Pipe Line Corp., Colorado City, Tex.
Goodwin, E. E., Westinghouse Elec. Corp., Kansas City, Mo.
Goss, A. L., Al Goss Elec. Co., Little Rock, Ark.
Green, T. J., Elec. Dept., Lubbock, Tex.
Hiers, W. A., Westinghouse Elec. Corp., Dallas, Tex.
Leach, L. B., Westinghouse Elec. Co., Kansas City, Mo.
Meadows, J. P., Southwestern Gas & Elec. Co., Marshall, Tex.
Moore, A. C., The Dow Chemical Co., Freeport, Tex.
Morris, W. T., Texas Elec. Service Co., Fort Worth, Tex.
Myers, F., Wagner Elec. Corp., St. Louis, Mo.
Phillips, R. E., Kansas Gas & Elec. Co., Wichita, Kansas
Shafer, E., Jr., Southwestern Public Service Co., Carlsbad, N. Mex.

8. Pacific

Alexander, M. H., Kern Mutual Tel. Co., Taft, Calif.
Bennett, M. N., Modesto Irrigation District, Modesto, Calif.
Daniel, J. N., Southern Calif. Edison Co., Los Angeles, Calif.
Elliott, J. L., Selenium Corp. of America, El Segundo, Calif.
Hobaugh, D. E., U. S. Bureau of Reclamation, Parker Dam, Calif.
Hughes, A. R., State of California, Sacramento, Calif.
Koenig, A. W., Consolidated Vultee Corp., San Diego, Calif.
Meyer, G. H. (re-election), Dept. of Water & Power, Los Angeles, Calif.
Miller, N. F., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Savitch, C., Southern Calif. Edison Co., Los Angeles, Calif.
Simons, L. F., Salt River Valley Water Users Assn., Phoenix, Ariz.
Smothers, D. M., C. F. Braun & Co., Alhambra, Calif.
Wasmuth, E. B., U. S. Bureau of Reclamation, Redding, Calif.
Whiston, W. F., San Diego Gas & Elec. Co., San Diego, Calif.

9. North West

Hing, P., West Oregon Elec. Co-op., Inc., Vernonia, Oreg.
Robertson, J. H., Permanente Metals Corp., Trentwood, Wash.
Singletary, Jr. W. R., 3540 N. E. Wasco St., Portland, Oreg.
Vosmer, A. L., General Elec. Co., Hanford Engr. Works, Richland, Wash.

10. Canada

Rockson, P., Phillips Elec. Works, Brockville, Ont. Canada
Wells, A. F., Trans-Canada Air Lines, Winnipeg, Manitoba, Canada

Elsewhere

Abhyankar, V. G., H. M. I. Dockyard, Bombay, India
Guha, N. C., Military Engineer Services, Namkum, Ranchi, Bihar, India
Malayan, A., Fr. Sauter, Ltd., Basle, Switzerland
Mejia G., A., Corp. Peruana del Santa, Lima, Peru, S. A.
Murugasu, V., Dept. of Broadcasting, Jurong, Singapore, Straits Settlements
Parish, A. R., The English Elec. Co., Ltd., Stafford, England
Petersen, S. R., "Esper Clemmensen", Copenhagen, Denmark
Roy, N. K., The Tata Iron & Steel Co. Ltd., Jamshedpur, India
Thompson, D., City of Birmingham, Elec. Supply Dept., Birmingham, England
van der Pals, W. J. V. E., Rijks Luchtvaart Dienst, Westermarkt, Amsterdam, Netherlands

Total to grade of Associate

United States, Canada, and Mexico, 144
Elsewhere, 10

OF CURRENT INTEREST

ASME Holds Fall Meeting in Salt Lake City, Utah

Technical and industrial advances in the western states were stressed in the program of the American Society of Mechanical Engineers during its fall meeting held in Salt Lake City, Utah, September 1–4, 1947. The 4-day meeting comprised some 17 technical and general sessions a few of which are reviewed in the following paragraphs.

KEYNOTE ADDRESS

Eugene W. O'Brien, president of the ASME delivered the keynote address of the meeting in which he predicted new economic gains in the West and in the South. The virtues of Utah's pioneers were praised and held up as examples for the United States to emulate during these trying times.

ATOMIC ENERGY

Speaking on atomic energy, its uses and abuses, Robert Sibley, a former vice-president of the ASME and executive manager of the alumni association of the University of California at Berkeley, urged international control of atomic energy. All nations, including Russia, must come under a plan where a whole and complete harmonization of effort to control its uses for the good of mankind, he said. An interesting new use of atomic energy was described by the speaker. This purpose was helping to obtain information concerning prehistoric man from certain limestone deposits in South Africa. In these limestones are skulls and fossil remains that have a great bearing in tracing the ancestry of man.

Unfortunately the fossil remains occur at irregular intervals. It is expensive to dissolve the limestone material to obtain the fossils. If other means could be found to photograph a piece of limestone so that any fossils existing within the deposits could be made known before expensive excavations were made, it would facilitate greatly the speed of the study and reduce the expense.

Experiments were conducted before an expedition outfitted by the university left for South Africa, using radioactive materials previously bombarded by the fast moving particles in the cyclotron. Means were found that will enable the scientists to acquire much information on the fossils without the necessity of dissolving the enclosing media.

MAN'S INERTIA DECRIED

Speaking at a luncheon jointly sponsored by the Sons of the Utah Pioneers and the ASME, Dean O. Meredith Wilson of the University of Utah told his listeners that the development in man of a feeling of hopelessness to combat the perilous forces of his modern environment was more dangerous to the peace of the world than the atomic bomb. He warned that as the Utah pioneers faced and conquered the difficulties which beset them, so men today must rise above their environment and force their imprint upon the world which surrounds them.

AIRCRAFT INDUSTRY PROBLEMS

Claude N. Monson, vice-president of Northrop Aircraft, Inc., Hawthorne, Calif., spoke on "Present and Future of the Aircraft Industry." He called for a strong government air policy, fully supported by the American people, to build and maintain the most up-to-date defensive air force in the world as an insurance policy for national security. The problems of the aircraft industry of today are the problems of every citizen of the United States. The industry should not be permitted to reach too low an ebb—national security depends upon it. He also outlined some of the technical problems still to be met such as friction, shock wave, and heat, all of which combine to make the creation of an aircraft capable of flying faster than sound extremely difficult.

Some of the current work under way at Northrop Aircraft was described. One of the projects is the adaption of the jet bomb, *JB1A*, which was manufactured for the Army Air Forces. In the adaption called for, because of the greater speeds required, there are many new physical problems such as a thin and rigid wing—a perfectly smooth air foil. The skin is fabricated of sheet magnesium machined to taper both ways. The skin of the control surfaces is of magnesium plate with the ribbing milled into it for the required strength. Heat generated from the high speeds will necessitate refrigeration of the pilot's compartment. Erosion produced by the elements may be one of the greatest problems, in that the material now used may not withstand the rain and wind blast at these high speeds.

The *B-35* Flying Wing Bomber which Northrop built for the Army Air Forces also is undergoing a new development. Two of these planes are being modified to jet propulsion at the request of the Army Air Forces. This will involve the use of eight jet engines making it, so far as it is known, the most powerful bomber in the world today. Northrop further is engaged, Mr. Monson said, in developing guided missile information for the Army Air Forces, a project which must take into consideration both subsonic and supersonic speeds with all the difficulties inherent therein. They also are engaged in nuclear energy research at the request of the Government to seek out ways to achieve new power performance for commercial and military aircraft.

SHASTA TURBINES AT COULEE

Two hydraulic turbines of 103,000 horsepower, designed for the Shasta power plant on the Sacramento River in California, were installed at Grand Coulee power plant on the Columbia River in Washington early in 1942 to supply power for war industries. The peculiar engineering problems involved, and the methods of solving them, were described by Herbert H. Sloane, engineer with the Bureau of Reclamation, Denver, Colo., at a hydraulic session. A proposal by reclamation bureau engineers to install temporarily in available space at Grand Coulee the first two of the 75,000 kw units completed for the Shasta power plant promptly was approved by the War Production Board.

Engineering problems involved the fact that the rated head of 330 feet the discharge of the Shasta turbine equals 3,200 cubic feet per second at full gate, and for the units of the Coulee plant, the corresponding design discharge is 4,500 cubic feet per second. Thus the Coulee draft tube is about 40 per cent larger than the Shasta tube. Records show that the two Shasta generating units performed well in their temporary location the speaker said. Although the units were rated at 75,000 kw, they were able to produce 84,000 kw continuously, and when a little extra power was needed it was possible for each unit to produce up to 92,500 kw until the peak demand was over. This performance was obtained throughout the length of their temporary service without any major repairs being needed to either machine. The reassembly of these units in their final location in the Shasta power plant is now nearing completion.

"SUPER" METALS DESCRIBED

Clyde E. Williams, director of Battelle Memorial Institute, Columbus, Ohio, and president of the American Institute of Mining and Metallurgical engineers, described a new group of "super" metals and ceramics that soon will be available for man's new high-powered machines. For such applications as the supercharger, disk materials must withstand a temperature of 1,100 degrees Fahrenheit under high stress. For this purpose, a chromium-nickel-cobalt-iron alloy strengthened with such other elements as molybdenum, tungsten, columbium, or titanium is used. The alloy used for disks contains 16

per cent chromium, 25 per cent nickel, 6 per cent molybdenum, and the balance is iron. To secure stability in gas turbine blades such as are used in superchargers and jet engines still more highly alloyed materials must be used and some are practically iron free.

The strongest materials suitable for precision casting are the cobalt-base alloys containing 40 to 70 per cent cobalt and such other additions as chromium and molybdenum, or chromium, nickel, molybdenum, tungsten, and columbium. Another series of alloys based on chromium with upwards of 50 per cent of this metal, is showing great promise. An example is one that contains 60 per cent chromium, 15 to 25 per cent molybdenum, and the balance iron. This alloy must be melted and cast in a vacuum. In preliminary tests it performs better than the cobalt-base alloys and gives promise of permitting safe use of still higher stresses.

The high-temperature "super" metals developed for gas turbines and future improvements will be useful, but to meet the highest temperatures requirements these will not suffice and ceramic materials will have to be used. These ceramic materials made up from the most highly refractory substances such as oxides of beryllium, aluminum, magnesium, zirconium, and so on, are the only known materials that will not melt or burn up at such high temperatures. They may be used as coatings for metals, as structural combinations with metals, or as individual parts. The relatively poor mechanical properties of ceramic materials necessitates further improvement by research or compensation for by design.

NEW RAIL DESIGN

An improved rail design was described by Walter Leaf, research technician of the Denver and Rio Grande Western Railroad, at a metals engineering session. The three new rail sections, approved by the rail committee of the American Railway Engineering Association and adopted as standard design after several years of experiment, are very similar to the design worked out by the Denver and Rio Grande Western Railroad which is, in effect, the old web turned upside down and thickened throughout, the speaker explained.

NORTHROP AWARDED MEDAL

Highlighting the annual banquet was the award of the Spirit of St. Louis gold medal, highest aviation honor given by the ASME, to John K. Northrop, president, Northrop Aircraft, Inc., Hawthorne, Calif.

Medical Operations Televised at Clinical Congress

Television broadcasts of surgical operations were shown to surgeons attending the 33d Clinical Congress of the American College of Surgeons which was held at the Waldorf-Astoria Hotel in New York City during the week of September 8, 1947. The broadcasts were presented to the surgeons as an indication of the possible application of television to surgical education.

They were made possible by the co-operative efforts of The New York Hospital, the American College of Surgeons, the Johnson and Johnson Research Foundation, and the RCA Victor Division of the Radio Corporation of America, which installed and operated the equipment.

The supersensitive RCA Image Orthicon television camera, requiring no special lighting, was installed on a specially constructed track about the operating table, permitting movement of the camera as required to obtain the best view of the incision and operative procedures. A microphone mounted near the camera picked up the running commentary of the operating surgeon. Pictures were transmitted from the hospital to the hotel by means of a television relay link, which employed a highly directional narrow beam which could not be picked up by other receiving antennas.

A cable running through a window of the tenth floor operating room in the hospital carried the signals to a directional antenna on top of the hospital building. From this antenna programs were beamed directly to a receiving antenna on the 18th floor terrace of the Waldorf-Astoria Hotel.

Seven television receivers were installed in a suite on the fourth floor of the hotel where seating facilities were provided for about 300 surgeons at a time. Two additional receivers were installed at the hospital, one in the operating room to enable the operating surgeon to see the operative area covered by the camera, and one in an adjoining office for the benefit of some members of the hospital staff.

This was the first time that televised pictures of surgical operations ever were transmitted from an operating room in one location to television receivers in another part of the city. In February of this year the first use of television in the operating room was made at a special clinic for visiting alumni at Johns Hopkins Hospital in Baltimore, Md., however, pictures and sound were transmitted only by wire to a viewing location within the same building.

New NBS Mechanics Chief. The appointment of Walter Ramberg as chief of the mechanics division of the National Bureau of Standards has been announced. He will succeed Hugh L. Dryden, who is leaving the bureau to become director of research for the National Advisory Committee for Aeronautics. Doctor Ramberg, who has been chief of a section in the mechanics division since 1946, has gained an international reputation for his work in aeronautics, particularly in the field of strength and stability of structural elements of aircraft. The most recent of a number of instruments developed by him—the vacuum tube acceleration pickup (*EE, June '47, pp 555–6*)—capitalizes on the internal vibration of a vacuum tube to measure changes in acceleration of vibrating parts of an aircraft in flight. The instrument also is proving useful in studies of the forces imposed on pilots in crash landings.

D. F. Roloff Dead. Delbert F. Roloff, assistant manager of General Electric Company's specialty transformer division and a well-known figure in the neon-sign industry, died recently in Fort Wayne, Ind. Roloff contributed to the rapid growth of the neon-sign industry and pioneered development of ignition transformers for oil burner applications. During the war he worked on applications of specialty transformers to aircraft. He was affiliated with the General Electric Company since 1919, having held various positions in the transformer engineering divisions in Fort Wayne, Ind., and Pittsfield, Mass. In 1946 he was appointed to the position of assistant manager of the specialty transformer division, a post he held until his recent death.

Cyclone Burner for Fisk Station in Chicago

When the recently ordered 150,000-kw turbogenerator goes into service in 1949 at Commonwealth Edison company's Fisk station, in Chicago, Ill., it will be driven by steam produced by a new type of furnace known as the cyclone burner.

Developed through years of co-operative research by Babcock and Wilcox Company, boiler manufacturer, the engineering firm of Sargent and Lundy, and Commonwealth Edison company, the equipment supplants the burning of coal on a chain grate or in pulverized form. An experimental furnace, installed in 1943 at Edison's Calumet station, in Chicago, Ill., has performed so well that the utility has decided to make the new units standard on newly ordered additions to its generating capacity.

The cyclone furnace is designed to burn the type of coal mined in central Illinois, the company's chief source of supply. The unit's main advantages are

1. Between 80 and 85 per cent of the coal ash is collected in the furnace itself and removed in molten form. This materially simplifies ash handling and substantially reduces the emission of dust through the stacks.
2. Retention of most of the ash in the furnace sharply reduces the amount of boiler tube cleaning. It also permits closer spacing of these tubes and thus contributes to greater compactness.
3. The cyclone furnace obviates the need for costly precipitator equipment used on conventional installations to remove fly ash.
4. It permits substitution of simple, easily maintained coal crushing equipment for the expensive pulverizers which are essential to present-day generating station furnaces fired with pulverized fuel.

The cyclone burner at Calumet station is a horizontal cylindrical chamber, 8 feet in diameter and 11 feet long. Closed at one end except for coal and air inlets, it has a restricted discharge opening at the other end. Coal crushed to one-fourth-

inch is introduced into the compartment with air at a velocity of about 300 miles per hour. This gives the mixture a cyclonic motion and results in split-second burning. The result of the greater compactness and simplified equipment is lower investment cost and saving in space.

Two boilers will supply the steam driving the new Fisk generating unit. Each will be fired by four cyclone burners and each will be capable of producing 750,000 pounds of steam per hour.

Electronics Aids Lumbermen in Logging Operations

Two-way radio was used to co-ordinate and expedite a major log drive this summer for the first time in the history of logging. Minnesota and Ontario Paper Company, Minneapolis, used frequency modulation radio equipment for this unique application to establish communication among widely dispersed logging units engaged in the summer movement of thousands of cords of pulpwood for paper and insulation board.

Basis of the novel use of radio is a recently installed frequency modulation network link between the company's mills at Fort Frances, on the international border, and Kenora, in the Ontario province of Canada, 93 air-miles to the north. Transmitters and 300-foot steel antennas are located at each site.

To cover the area completely, two relay stations were established about 60 miles from each station. The four key stations make it possible for nine radio-equipped logging camps scattered throughout the surrounding area to send and receive messages, either by direct communication or by relay, to any of the other stations in the network.

The portable stations for the log drive by radio are a 60-watt General Electric Company frequency modulation transmitter and receiver, shock-mounted in a small taxi-size wardrobe trunk. When the trunk lid is open a control panel is exposed which contains a loud-speaker, the necessary controls, and a wall bracket to mount and hold the telephone handset. In the upper right hand corner of the trunk is located an antenna mounting bracket. The complete station can be assembled and put on the air in less than five minutes.

Philadelphia Mediation Council Organized for Labor Disputes

An organization for the voluntary settlement of labor-management disputes without recourse to government intervention has been established in Philadelphia, Pa., as a means of preserving industrial peace. Known as the Philadelphia Mediation Council, it consists of an advisory and policy-making board of six management and six labor representatives and a panel of mediators chosen by the two groups. The council was formed by the Chamber of Commerce of Philadelphia and the Philadelphia Industrial Union Council (CIO) to handle "local disputes by local people." American Federation of Labor affiliates have been invited to join.

Representing management on the council are William L. Batt, president of SKF Industries, Inc., and former vice-chairman of the War Production Board; Joseph G. Pew, Jr., vice-president, Sun Shipbuilding and Drydock Co.; Joseph Schmitz, president, Universal Dye Works; Emery W. Loomis, regional manager, Westinghouse Electric Corporation; Clement V. Conole, general manager, and Rudolf F. Vogeler, manager of the Industrial Council, Chamber of Commerce.

Labor representatives are Michael Harris, president of the Industrial Union Council and district director of the United Steelworkers; Joseph Hueter, Textile Workers Union of America; Charles Weinstein, Amalgamated Clothing Workers; William M. Leader, American Federation of Hosiery Workers; Joseph B. Dougherty, Transport Workers Union, and James Price, United Electrical, Radio and Machine Workers.

Doctor George W. Taylor, professor of industry at the University of Pennsylvania, Philadelphia, Pa., and former chairman of the National War Labor Board, is chairman of the mediation council.

Aims and objectives of the council are

1. To avoid strikes and lockouts through the most effective use of mediation.

2. To develop understanding and co-operation between management and labor through the medium of friendly discussion and frank conference.

3. To observe the law as the charter by which the rights of all citizens are assured.

4. To advance the interests of the public through effecting industrial harmony by the use of voluntary procedures in handling labor-management problems.

5. To recognize and preserve the fundamental rights of labor to organize and to engage in collective bargaining with management. Through the acceptance of collective bargaining, differences between management and labor can be disposed of between the parties by peaceful means, thereby discouraging avoidable industrial strife.

6. To recognize and preserve the inherent right and responsibility of management to direct the operation of an enterprise.

7. To observe contracts, collective bargaining or otherwise, with equivocation or evasion.

In the event of an industrial deadlock, either party may bring an existing or impending dispute before the council which can proceed only with the consent of the disputants. The council then will select mediators who will attempt to have the parties negotiate an agreement.

Where mediation fails, council representatives will analyze the facts and make recommendations as a basis for further opportunity to reach an agreement. If settlement is not achieved by the first two steps, the council representatives will explore the possibility that the parties voluntarily submit disputed issues to arbitration.

Artificial Crystals Mass-Produced for Telephone Circuits

Artificial crystals, grown in the laboratory from ordinary chemicals, are starting to be used in the United States expanding telephone network as a substitute for scarce but indispensable natural quartz.

In a few years, the artificial crystals are expected to replace as much as 90 per cent of the natural quartz used in long-distance telephone systems. Some New York to St. Louis circuits already are operating with synthetic crystal units. Additional urgently needed long-distance circuits are expected to go into operation appreciably earlier than otherwise possible as a result of development of the new crystal.

Bell Telephone Laboratories, New York, N. Y., developed the crystal-growing technique, and Western Electric Company, has constructed a crystal plant at Allentown, Pa., to mass-produce the new crystals for use in long-distance telephone circuits.

The new crystals, ethylene diamine tartrate, are known familiarly as *EDT*. Although these crystals differ markedly from quartz in chemical composition, both are piezoelectric in character; that is, they can convert mechanical energy to electric energy or they can reverse the process.

The new crystal is the direct result of long-range research on growing artificial crystals which has been in progress at Bell Laboratories for a quarter of a century. During the war the research program led to the development of synthetic crystals for use in sonar, the underwater equivalent of radar. Those crystals were composed of ammonium dihydrogen phosphate, abbreviated to *ADP*.

In co-operation with Bell Laboratories, Western Electric Company mass-produced some 20,000,000 of the crystals for United States Navy sonars in one of the most closely guarded projects of the war.

In the telephone system, the crystals are used to filter or separate various voice channels traveling over the same telephone circuit. Heretofore, telephone filters used quartz crystals which occur in suitable size only in nature. With the present increased demand for long-distance telephone circuits, the supply of quartz, already heavily drained for war needs, proved inadequate.

The Allentown plant of Western Electric Company, geared to produce hundreds of thousands of crystal plates a year, was established after extensive development work and pilot plant operations at Bell Laboratories. In commercial production the artificially grown crystals weigh about a pound and are about six inches in length and two by three inches in cross section.

These full-grown crystals are cut into plates, roughly an eighth of an inch thick, an inch and a half long, and a half-inch wide, and are coated with a film of gold hardly a millionth of an inch thick, which serves as an electrical connection. They then are mounted in a glass envelope to form a crystal unit.

The first tiny seeds of crystal from which subsequent crops were harvested were only a third of an inch across. They were obtained by evaporating a saturated

solution of the chemical in a dish. These then were swished slowly back and forth in a solution of the chemical which was kept supersaturated. Slowly, more crystal was added to these seeds—that is, they grew. The entire growing process must be controlled very precisely. Temperature variations, for example, must be kept within a tenth of a degree.

A crop of crystals can be harvested every three months, and the seeds cut off from the new growth and replanted in the solution to start another crop.

Eta Kappa Nu Awards Resumed for Young Engineers

Presentation of the Eta Kappa Nu awards for outstanding young electrical engineers, which was suspended during the war years, will be resumed at ceremonies to be concurrent with the AIEE winter general meeting in Pittsburgh, Pa., during the week of January 26, 1948. Selection of six winners will be made by a committee from a field of 92 candidates.

Inaugurated in 1936 to recognize "meritorious service in the interests of their fellow men" the Eta Kappa Nu recognition award is given to standing young electrical engineers, graduated not more than 10 years, and less than 35 years of age. Careful consideration is given to civic, social, and cultural activities, as well as to technical achievements, in making the final choices.

One award will be made for each of the years 1942 to 1947 inclusive, together with honorable mention awards. Each of the 92 candidates will be eligible for an award on the basis of his eligibility in the award year for which he may be selected.

Eta Kappa Nu is an honorary electrical engineering fraternity, which presented its last award for 1941. Candidates are nominated by heads of college electrical engineering departments, personnel directors of electrical industries, and AIEE Sections.

Technical Papers on Dam Construction Requested

Engineers throughout the United States have been requested to submit technical papers on a selected list of subjects concerned with dam construction for the Third International Congress on Large Dams, to be held in Stockholm, Sweden, in 1948 as an activity of the Third World Power Conference. The call for papers was issued by the International Commission on Large Dams in conjunction with a meeting of its executive committee, held September 3, 1947, at The Hague, for consideration of the agenda for the Stockholm conference.

Engineers are requested to submit their papers through the chairman of the United States Committee of the International Commission, Michael W. Straus, Commissioner of Reclamation, Washington, D. C. They are urged to get them into the chairman's hands at the earliest possible time, but not later than December 1, 1947.

The executive committee listed the following subjects on which technical papers are desired:

1. Uplift on dams and uplift stresses.
2. Research instrumentation and results in measuring stresses and strains in concrete and earth dams.
3. Methods of controlling "piping" in earth dams.
4. Experience resulting from the use of special cement in large structures.

Nuclear Book Series to Be Published

John Wiley and Sons, New York publishers of scientific and technical books, have announced publication plans for a series of advanced books on related aspects of the nuclear sciences. These books are to cover the physics, chemistry, biology, metallurgy, medicine, and engineering aspects of nuclear science.

Among the books for which concrete plans have already been projected is one on the separation of isotopes, by Doctor Harold C. Urey, 1934 winner of the Nobel Prize in chemistry; and Doctor Karl P. Cohen, of the development division of Standard Oil Company of New Jersey's Linden Laboratories. In the field of medical physics, Doctor Joseph Hamilton, of the University of California, is preparing a book entitled "The Application of Radioactive Tracers to Biology and Medicine." Biological aspects of nuclear studies will be covered in a book on radiobiology—cellular and mammalian—to be written by Doctor Raymond E. Zirkle, director of the University of Chicago's Institute of Radiobiology and Biophysics. Doctor Marcel Schein, of the University of Chicago, is heading a group which will collaborate on a cosmic ray symposium. Volumes on neutron physics, experimental nuclear physics, a general survey of theoretical nuclear physics, nuclear instrumentation, radiochemistry, radioactive tracers, an isotopic carbon treatise, the structure of matter, and radiation protection also are being planned. These works are to be written by a distinguished group of atomic scientists, including several Nobel Prize winners.

The first work in this series was released recently; it is called "Elementary Nuclear Theory," by Hans A. Bethe, professor of physics at Cornell University.

OTHER SOCIETIES •

112th ACS Meeting Held in New York City

The 112th national meeting of the American Chemical Society was held in New York, N. Y., September 15–19, 1947. Nearly 1,000 technical papers were presented in sessions of the society's 18 professional divisions. Some 124 local sections of the society were represented at the meeting for which the general headquarters was the Hotel Pennsylvania in New York.

Recent advances in nuclear chemistry, food protection, petroleum, and plastics; improved methods of purifying water supplies; new developments in fluorine chemistry; and progress in the production of synthesis gas were among the subjects discussed in the various technical sessions of the meeting.

FOREIGN PROGRESS

Scientific conditions abroad were surveyed in two addresses by leading chemists during the week. "Science and Industry in Japan" was discussed by Doctor Roger Adams, chairman of the American Chemical Society's board of directors and head of the department of chemistry in the University of Illinois, Urbana, Ill., at a luncheon of the division of industrial and engineering chemistry. Doctor Adams headed a scientific mission sent to Japan

Future Meetings of Other Societies

American Institute of Chemical Engineers. Annual meeting, November 9–12, 1947, Detroit, Mich.

American Institute of Mining and Metallurgical Engineers. Annual meeting, February 15–19, 1948, New York, N. Y.

American Society of Refrigerating Engineers. Winter meeting, December 8–10, 1947, Atlantic City, N. J.

American Society of Mechanical Engineers. Annual meeting, December 1–5, 1947, Atlantic City, N. J.

American Society for Testing Materials. Spring meeting and committee week, March 1–5, 1948. Washington, D. C.; annual meeting, June 21–25, 1948, Detroit, Mich.

Canadian Institute of Radio Engineers. Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

CIGRE (International Conference on Large Electric High-Tension Systems). Biennial meeting, June 24–July 3, 1948, Paris, France.

Conference on X-ray and Electron Diffraction. November 7–8, 1947, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Exposition of Chemical Industries. 12st annual exposition, December 1–5, 1947, New York, N. Y.

Institute of Radio Engineers. Fall meeting held jointly with the **Radio Manufacturers Association Engineering Department,** November 17–19, 1947, Rochester, N. Y.; annual convention and radio engineering show, March 22–25, 1948, New York, N. Y.

International Lighting Exposition and Conference. November 3–7, 1947, Chicago, Ill. Sponsored by National Electrical Manufacturers Association.

National Academy of Sciences. Meeting, November 17–19, 1947, Washington, D. C.

National Association of Manufacturers. 52d Annual Congress of American Industry, December 3–5, 1947, New York, N. Y.

National Electrical Manufacturers Association. Winter convention, March 14–18, 1948, Chicago, Ill.

National Electronics Conference. November 3–5, 1947, Chicago, Ill.

National Materials Handling Exposition. January 12–16, 1948, Cleveland, Ohio.

National Society of Professional Engineers. December 4–6, 1947, Buffalo, N. Y.

Refrigeration Equipment Manufacturers Association. All-Industry Refrigerating and Air-Conditioning Exposition. January 26–29, 1948, Cleveland, Ohio.

this summer to advise General Douglas MacArthur's staff on the democratization of science. The other address was, "Some Aspects of the European Scientific Situation," which was the topic of Professor George Scatchard of Massachusetts Institute of Technology, Cambridge, Mass., who addressed the division of physical and inorganic chemistry at a dinner.

SCIENTISTS HONORED

Seven outstanding scientists were honored for their contributions to chemistry. The Priestley Medal, highest award in American chemistry, was conferred upon Professor Warren K. Lewis of Massachusetts Institute of Technology, Cambridge, Mass., for distinguished services to chemistry. Professor Lewis spoke on "The Kinetics of the Reactions of Steam and Carbon Dioxide With Carbon."

Professor Glenn T. Seaborg of the University of California, Berkeley, Calif., codiscoverer of plutonium and a member of the general advisory committee of the United States Atomic Energy Commission, received the $1,000 American Chemical Society award in pure chemistry, given by Alpha Chi Sigma, national chemical fraternity for his achievements in nuclear science. He delivered an address on "Nuclear Transformations in the New High Energy Ranges." Others who received awards are Professor Mary Lura Sherrill, head of the department of chemistry in Mount Holyoke College, South Hadley, Mass., the Francis P. Garvan Medal honoring women in chemistry; Professor Van R. Potter of the McArdle Memorial Laboratory for cancer research, University of Wisconsin medical school, the Paul-Lewis Laboratories award in enzyme chemistry; Doctor George C. Supplee, head of the G. C. Supplee Research Corporation, Bainbridge, N. Y., the Borden award in the chemistry of milk; Doctor Sidney P. Colowick of the Public Health Research Institute of the City of New York, the Eli Lilly and Company award in biological chemistry; and Doctor Louis Schmerling of the Universal Oil Products Company, Chicago, Ill., the new $3,000 Ipatieff Prize for achievement in the field of catalysis.

Doctor W. Albert Noyes, Jr., president of and chairman of the department of chemistry at the University of Rochester, Rochester, N. Y., described "The Mechanism of Photo Chemical Reactions" in his presidential address.

NOBEL PRIZE WINNERS SPEAK

Professor Harold C. Urey of the University of Chicago, Chicago, Ill., who won the Nobel Prize in 1934 for the discovery of heavy hydrogen, presided at a symposium on the use of isotopes as tracers in biochemical studies of the fundamental processes of life. The session was sponsored jointly by the physical and inorganic division and the biological division of the society.

Another Nobel Prize winner, Professor Peter J. Debye of Cornell University, Ithaca, N. Y., who won the chemistry award in 1936, presented a paper on "The Contribution of Physical Methods" at a symposium on the purity and identity of organic compounds sponsored by the physical and inorganic division of the society.

New Secretary for AWS. The board of directors of the American Welding Society unanimously have selected Joseph Gordon Magrath for the new position of executive secretary of the society. As the chief staff officer of the society, Magrath will work with other members of the national headquarters staff in directing the activities of this national engineering organization of about 7,500 members. M. M. Kelly, secretary; W. Spraragen, editor of the *Welding Journal* and director of Welding Research Council; and S. A. Greenberg, technical secretary; will continue in their present duties.

Instrument Conference Held. More than 7,000 instrument engineers, production executives, chemists, and instrument men attended the Second Annual Conference and Exhibit in Chicago, Ill., during the week of September 8, 1947. Instruments and control devices were shown by some 135 companies and 4 government agencies. The technical program was sponsored jointly by the Instrument Society of America and the industrial instruments and regulators division of the American Society of Mechanical Engineers. The next annual meeting of the society will be held in Philadelphia, Pa., September 13–17, 1948.

RMA Labor Seminar. The Radio Manufacturers Association's industrial relations committee announces that a fourth RMA industrial relations seminar will be held November 13, 1947 at the Stevens Hotel, Chicago, Ill. This seminar, which will be under the direction of R. C. Smyth, industrial relations director of the Bendix Radio division, Baltimore, Md., will deal chiefly with the application of the Taft-Hartley Act to the radio industry.

EDUCATION . . .

GE Scholarships and Loans. Awards of 46 scholarships and loans, totaling $14,650, to employees and children of employees have been announced by the General Electric Company, Schenectady, N. Y. Nineteen scholarships for undergraduate study were granted, including 13 under the General Electric Employees Education Foundation, part of a $1,000,000 educational fund established in 1945 in honor of two former company presidents, Charles A. Coffin and Gerard Swope (F '22). The John E. Popper scholarship established by Popper, a former employee, and later augmented by the company, was made to John H. Smith of Bridgeport, Conn., who is employed by the General Electric apprentice drafting division at Bridgeport, Conn. The scholarship provides $500 per year for a 4-year course of undergraduate study at any accredited college or university. The remaining five scholarships, all at Union College, Schenectady, N. Y., were granted under the Charles P. Steinmetz Memorial Fund established 25 years ago in honor of one of the company's most eminent scientists. In addition, eight Gerard Swope loans were granted for study at Union College and 19 loans were granted under the Employees Education Foundation for study at various institutions.

Urban Transit Course. A course in urban transit now is being taught at New York University, New York, N. Y., which is open to students seeking credit towards degrees, as well as those employed in the transit industry. The course is designed to give students a general knowledge of the business and economic aspects of transit operation. It is being given under the direction of the New York Department of Public Utilities and Transportation at the Washington Square college of the university.

New RPI Degrees. Rensselaer Polytechnic Institute, Troy, N. Y., now is conferring two new degrees, bachelor of science in vocational education and a master of science in education. These degrees are being conferred under a special program for educating more and better high school teachers in science, technology, mathematics, and vocational education. Under the plan, students attending the State College for Teachers at Albany, N. Y., for example, will take courses in engineering, applied science, mathematics, drawing, industrial and technical education, and in more general subjects by attending evening, Saturday, and summer courses set up at RPI especially for the purpose. The same courses on both undergraduate and graduate levels also will be available for the upgrading of both men and women who already are teaching in schools throughout this state and in others. The New York State Department of Education and the State College for Teachers are co-operating in this program.

Communication Curriculum Revised at Washington

The George Washington University school of engineering, Washington, D. C., has revised and extended its curriculum for the communications option in electrical engineering. Under the new program students begin their option in electrical engineering in the second half of the junior year instead of in the senior year.

New wartime developments including the whole field of wave guides and radio wave propagation are being added, and obsolete material has been eliminated.

New courses include advanced network theory including wave guides, radio wave propagation with laboratory, application of electronic devices, and an advanced class in pure electronics including advanced tube theory on specialized tubes such as magnetrons and klystrons.

HONORS • • • • • •

Lincoln Foundation Awards Resumed

The trustees of The James F. Lincoln Arc Welding Foundation have announced the rules of their annual engineering undergraduate award and scholarship program. This program started in 1942 but was interrupted by the war. Recently, upon the advice of the deans of engineering of a number of prominent engineering schools, it was decided that the time had arrived when the program should be resumed.

The foundation sponsors a series of $6,750 annual engineering undergraduate awards and scholarships.

This program contains two interdependent plans; the award plan and the scholarship plan. Under the award plan, engineering students of various engineering schools and colleges will submit papers on arc-welded design and the use of welding in maintenance of machines and structures. Under the scholarship plan, scholarships will be allocated to the schools in which the three highest award recipients under the award program are registered.

Awards for papers, totaling $5,000, will be made as follows:

Number of Awards	Amount of Each Award
1	$1000
1	500
1	250
4	150
8	100
12	50
50	25
77 (Total)	

The scholarship plan will operate in the following manner. The institutions in which the three top awards are made to students will receive amounts of money equal, respectively, to those awards. These amounts are to be used for the purpose of scholarships in the departments in which the award students are registered. The department of the institution in which the first award winner is registered will receive $1,000 for four annual scholarships of $250 each. The department of the institution in which the second award winner is registered will receive $500 for two annual scholarships of $250 each. The department of the institution in which the third award winner is registered will receive $250 for one annual scholarship of $250. The total amount of scholarship funds awarded will be $1,750.

Students' papers are to deal with design for arc welding of parts of machines, complete machines, trusses, girders, structural parts, or their maintenance. It is not necessary that the machine, structure, or part, actually be built, but the design or method of construction must be described in the paper. The student need not necessarily adapt arc-welded construction to a complete machine or structure but may choose any part of a complete machine or structure, now usually made by other methods, which could be made by this method of construction; or he may conceive of a machine, structure, or part which never has been built but could be built by arc welding.

Resident engineering undergraduate students registered in any school, college, or university in the United States, which offers a curriculum in any branch of engineering (including agricultural engineering) or architecture leading to a degree, and cadets registered in the United States Military Academy, United States Naval Academy, and Coast Guard Academy are eligible to submit papers in this award program.

In rating the merits of the paper, the jury of award will give proper consideration to:

Ingenuity and originality displayed.

Clarity of design and description.

Practicability of the conversion described.

Technical completeness and thoroughness.

Statement of advantages such as savings in time or money or improvements in performance and social advantages, of the construction, or design, described in the paper, over other methods.

Presentation: correct use of English; quality of illustrations; neatness; succinct expression.

The rules of the program were reviewed and approved by the deans of engineering of 14 prominent engineering colleges. Papers must be postmarked not later than midnight, May 15, 1948, and awards will be announced as soon thereafter as is practical.

Copy of the rules and conditions may be obtained by writing The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

RESEARCH • • • •

X-Ray Photometer Speeds Chemical Comparisons

Economical and rapid means of making chemical comparisons is provided by a new instrument known as the X-ray photometer. With this device it has been found possible to determine satisfactorily the tetraethyl lead content of gasoline, the concentration of an acid in water, the per cent chlorination of a plastic, or the per cent ash in coal. These determinations are made by measuring and comparing the X-ray absorption of a sample and a reference.

Essentially this device consists of a source of X-rays, a fluorescent screen and multiplier phototube, an amplifier, and an indicating instrument. The X-ray beam is interrupted by a synchronous motor-driven chopper in such a way that half of the beam passes alternately through each of two analyzer cells, one containing the reference and the other containing the sample. In the half of the beam passing through the reference there is placed also an aluminum attenuator disk, the angular position of which corresponds with a particular thickness of metal.

The X rays from the two halves of the beam are received alternately on the fluorescent screen, from which the fluorescence is transmitted to the multiplier phototube. The output of this tube passes through an amplifier to a peak comparator where it registers on a microammeter as a d-c signal indicative of the difference in intensities of the two halves of the beam.

If the sample and the reference are identical the intensities of the two halves of the beam as received on the fluorescent screen are equal and the ammeter reading is zero without the use of the attenuator. If the sample and the reference are different it becomes necessary to introduce aluminum by means of the attenuator until the two halves of the beam become of equal intensity and the reading returns to zero. From the thickness of aluminum introduced into the reference half of the beam it is possible to determine empirically the proportion of certain elements in the sample as compared with the reference. In general the method is most applicable where there is a considerable difference in the atomic numbers of the main substance and the particular ingredient to be measured.

In actual operation the X-ray photometer has been found to work satisfactorily up to a speed of six samples per hour. Under most circumstances the limiting factor has been found to be the time required for the preparation of the sample. Liquids, which must be measured as they are put into the analyzer cell, require more time than solids when the latter are specimens of uniform thickness. Powdered solids such as coal, which must be weighed into the analyzer cell, require more time than liquids. Preparation of the samples, however, can be arranged independently of the operation of the instrument. If this is done there is no difficulty in maintaining the six per hour rate regardless of the physical form of the material to be tested.

An outstanding advantage of this method of comparison is that it is independent of the physical state of the substance being tested, because the amount of X-ray absorption by a given mass of material is always the same, whether the material is hot or cold, gaseous, liquid, or solid.

Similarly, because X-ray absorption is an atomic property, measurements will be identical when an element is alone and when it is in chemical combination. An oxygen atom, for instance, will register the same whether it is as an element or in any oxygen compound.

Other advantages of the X-ray photometer method of chemical comparison are its speed and convenience. The complete apparatus is housed in a mobile cabinet of moderate size, and can be operated by any reasonably competent technician. Furthermore the analysis is made without loss or alteration of the sample tested.

Electron Linear Accelerator Developed at Stanford

Doctor William W. Hansen, director of the Stanford microwave laboratory, described the successful operation of an electron linear accelerator to the Institute of Radio Engineers West Coast convention in San Francisco, Calif., on September 25, 1947.

The Stanford physicist, coinventor of the Klystron, heart of wartime microwave radar, reported that a 3-foot section of the electron accelerator has produced electrons of more than a million and a half volts.

He predicted that a projected larger model, 100–200 feet long, would develop billion-volt electrons, which would be the highest charge of electricity ever produced by man.

The electron linear accelerator, constructed at Stanford under a contract with the Office of Naval Research, would make available an artificial source of cosmic rays, elusive and mysterious light energy which bombards the ionosphere from outer space. At present the best source of cosmic rays for scientific study has been stratosphere airplanes equipped as flying laboratories.

In contrast to the massive cyclotron, which accelerates the heavy positively-charged particles of an atom, the Stanford accelerator concentrates its power on the electron, the light negatively-charged outer particle of the atom.

Atomic disintegration occurs in the accelerator when a speeding electron to which tremendous energy has been imparted by acceleration, strikes an atom which happens to be in its path. The process is similar to that of the cyclotron except that the "atomic bullet" is a different part of the atom and the "bullet" is going in a straight line instead of being whirled in a circle in a magnetic field.

In its present stage of development, the energy source used by the electron accelerator is a million watt magnetron of the type developed for wartime radar. Doctor Hansen said that he hopes to use 1,000 million watts of power in the projected larger model of the accelerator which will aim at a billion volt electron.

Since a million watts would burn out the equipment if used for more than a fraction of a second, the accelerator runs for only a millionth of a second, then is turned off for a sixtieth of a second before being run again.

The magnetron which powers the linear accelerator, shoots a microwave with a 4-inch wave length into a pipelike tube which lies horizontally on a steel frame. The wave runs down the tube, with the electron riding on the wave and getting constantly speeded up, much like a surfboard riding along on the sloping crest of a wave and going faster and faster.

Although there is a limit set by the law of relativity which makes it impossible for the electron to go faster than the speed of light, the energy imparted to the rapidly speeding electron results in an increase in its mass so that at the peak of its trip down the accelerator tube, it weighs 2,000 times more than when at rest.

The electron must travel at the exact speed of the microwave and to accomplish this the wave is made to travel over a series of circular disks in the tube; these finely machined disks serve as hurdles which slow the wave down so that its speed and that of the slower electron are identical. The disks that line the tube are gold-plated, and other sections of the tube and disks are silver-plated.

The electron linear accelerator has certain advantages over the synchrotron, another tool in the scientists atom-smashing equipment. A synchotron built by the General Electric Company has produced 100 million volt electrons, but the advantage of the electron linear accelerator over the synchotron is that it is a much simpler apparatus and therefore far cheaper to build.

And while there seems to be a definite limit to the maximum energy one can develop with the synchotron, the only limits to the energy which the linear accelerator can produce appear to be those imposed by the time and trouble and expense which it will take to build bigger accelerators.

One of the most important scientific applications of the electron linear accelerator will be its ability to produce cosmic rays. Scientists do not know of what these rays are made, and while the linear accelerator will not produce cosmic rays which have the maximum energies of those in space, it will produce rays which correspond to fairly energetic cosmic rays, and it is expected that having a ready source of cosmic rays in laboratories will contribute to the knowledge of these mysterious rays.

The linear accelerator also will offer another means of gaining information about the performance and constitution of the electron, which is one of the fundamental particles of matter. Like the cyclotron, it is expected to produce isotopes, which are materials chemically identical with known elements but differing in atomic weight. These isotopes, however, can be produced more practically in atomic piles.

The electron linear accelerator never will serve as a commercial source of power, according to Doctor Hansen, for while it produces a few electrons with enormous energy, on the average it develops less power than is put into it.

Researchers who have assisted in various stages of the electron linear accelerator experiment include Doctor E. L. Ginzton, of the physics department faculty, and W. R. Kennedy and Richard Post, both graduate students in physics.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Engineering Curriculum

To the Editor:

After reading with a great deal of interest the discussion on proposed changes in the engineering curriculum (*EE, Aug '47, pp 816–18*), I would like to express my views on the subject. With a background of 40 years in engineering work, hiring large numbers of young engineers, and being associated with them in their work, I think that I possibly may make some small contribution to the subject.

A young man entering engineering school may have a very definite idea as to the exact course of study and the exact place he will want to fill in the industrial picture of the future. However, he cannot possibly see far enough into the future, so that an exact course can be laid out for any great length of time. When he has completed four years at college and another ten years in industry, the whole situation for him and for industry has changed greatly.

An illustration of the uncertainty of future developments is the petroleum engineer. Only a few short years ago there were no petroleum engineers. That branch of engineering had to start with engineers who had the basic training of other branches and learned as they went along.

A large number of colleges and universities, particularly the smaller ones, are offering many courses in engineering—

to name only a few: electrical, electronic, mechanical, petroleum, chemical, civil, airplane design. It is next to impossible to get all the basic engineering subjects plus a considerable amount of cultural, educational, and specialized courses in the four years alloted to the regular engineering course as it now is taught.

Even though their thoughts and desires at the time of entering college are devoted wholly to being a particular kind of engineer, all young men should give some consideration to their ultimate goal in life. An engineer worthy of the name is, and should be, ambitious enough, so that he will not want to be limited by his education if it can be avoided. He, therefore, should consider where he hopes to be perhaps 40 years after leaving college.

If he aspires to be a chief electrician, then he has little to consider if, for example, he is an electrical engineering student. But suppose he hopes to become chief engineer; then he must consider additional studies in mechanical branches such as internal combustion engines, steam turbines, and various other mechanical subjects which generally are not pursued far enough in most electrical courses. In addition he may have the ambition ultimately to become an executive, such as vice-president in charge of engineering. For the position of chief engineer or vice-president in most organizations, the regular course of study, as taught in the average university or college, is not sufficient educational background.

Most large companies employing many engineers select them from students of all branches of engineering. There is always the possibility that any one of them may become chief engineer, or even reach an executive position. A broader knowledge of engineering then will be necessary or, at least, lack of it will be a handicap.

To overcome this deficiency, I believe that the regular engineering course should consist of the basic engineering subjects of all branches of engineering plus such educational and cultural subjects as can be crowded into the regular 4-year course. Such courses should be recognized with a bachelor of science degree, and any specialization should come later—one or two years additional work with possibly a master's or some other degree for completion. These degrees would be similar to the legal profession's bachelor of arts and bachelor of laws degrees.

Most organizations find some kind of a training course necessary for young graduate engineers. The graduate of a 4-year course offering basic study in various branches of engineering would be ready for such training (assuming that he had no desire to, or could not spend more time at college). If he wished to enter a specific branch of engineering later in life, he would have the basic training, and it would no be too difficult to pick up the necessary specialization.

Furthermore, if he so desired he could complete six years of study, for example, and be ready immediately to follow a specialized branch of engineering. If, as often happens in later life, he wished to change to another branch, it would not be too difficult.

A hypothetical case will make this clearer. A young engineer dreaming about taking electrical engineering and ultimately working in the utility field, especially in power, should take the courses leading to his goal. But he should consider that some day he may have supervision over large power plants containing steam engines, steam turbines, and internal combustion engines and should add to the electrical course after graduation by taking additional machine design, thermodynamics, and subjects which are not covered fully enough in the regular electrical course.

After graduation he may spend ten years in the electric railway business, in which all of those subjects are imperative. If then he leaves the utility business for another phase of engineering offering greater opportunity, it will be very difficult, without the training of both the electrical and mechanical courses, to succeed in the new job.

A. D. STODDARD (M '36)

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Forces Between Moving Charges

To the Editor:

In a recent letter (*EE, July '47, p 741*) Doctor Slepian accepts in principle the premise that the forces between moving charges depend upon the relative velocity of the charges with respect to each other. His espousal of this view is gratifying but it seems that his further insistence that results must be evaluated in terms of what an observer notes only obscures the basic issue. Disregarding the observer, we simply have a set of formulas which state that certain conditions exist (no matter how they are determined) and therefore certain results must follow (regardless of who measures them). On the other hand we have an observer who notes that certain results occurred because certain conditions prevailed, the magnitudes of which are determined in the observer's particular terms, not only for the results as Doctor Slepian requires, but also, of necessity, for the causative conditions. When each case is evaluated in its own consistent set of units with the correct pertinent formulas, the two methods are equivalent and the results identical, as was shown for a particular instance in the writer's letter which immediately follows Doctor Slepian's in the same issue of *ELECTRICAL ENGINEERING*.

Basically, one would suppose that the processes of nature must proceed according to certain definite laws, irrespective of the presence of man, and that man's influence on the result is limited to the extent to which he can control the causative conditions. A logical and natural corollary, which apparently appeals as much to Captain Cullwick as it does to the writer, is that the influence of systems upon each other depends only upon the relative values of the determinant parameters (velocity in the case under discussion).

Doctor Slepian states that the observer will define the electric and magnetic fields in terms of the force produced upon charges. This is a very significant statement, in which the use of terms is particularly apt. These so-called fields are to be recognized as merely *defined* quantities, representative of a condition of space involving forces due to the relationship of charges with respect to each other. Let us examine these forces and relationships. One force involves only the distance of separation of the charges, and is recognized as the electrostatic force. Another involves the velocities in some way, being recognized as the electromagnetic group, presently under discussion. The point primarily at issue is whether absolute or relative velocity should be used. It is strange that so much difference of opinion should arise on this point, whereas no concern ever is expressed over the fact that the distance of separation which governs the magnitude of the electrostatic force is a relative parameter. Relative velocity is only the time rate of change of distance of separation. A self-consistent set of formulas can be developed on that basis, and has been done by the writer, to which reference is made in the previous afore-mentioned letter.

There is a third force, commonly recognized as "transformer" or inductive effects, wherein the acceleration is involved in some way (di/dt in the usual formulas). Following through with the principle of relative parameters, it is proposed that these inductive effects depend upon relative acceleration, which is nothing more than the second time rate of change of distance of separation. Thus all known electric and electromagnetic phenomena, comprising the entire gamut of electrostatic, electromagnetic, and inductive effects, are to be recognized as a related group of forces involving the time relation of a common parameter. The writer has given this concept some consideration and has been led thereby along some extremely interesting byways of thought.

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Technical Preparedness

To the Editor:

As a nonmember of your Institute, I should like to comment on one phase of the San Diego meeting which stimulated private discussion, and which may be of interest to your readers.

For part of the program, your communications committee provided the members of the AIEE with a relatively new subject. Until recently, and for obvious reasons, subaqueous communications remained primarily of military interest. Hence, the papers presented during the Friday sessions described engineering developments utilized by the Armed Forces. In the opening paper of the sonar session, Captain Rawson Bennett pointed out that peacetime research

between World War I and World War II made possible the winning of the submarine battles in the Atlantic; also, that even now now as we are attempting to establish peace throughout the world, it is unfortunately and regrettably necessary to prepare for war. The same idea was expressed by Doctor A. W. Bellamy on Thursday evening in discussing the United Nations' attempt to form an international world state.

As enlightened citizens, a number of the members of the AIEE expressed a keen interest in the social implications of the military "gadgets" which were described. In the lobby and at the luncheon table immediately after the morning sonar session, one heard thought-provoking questions and discussions to this effect: "Isn't it a pity that such carefully developed equipments into which went so much technical skill and talent had to be made for war purposes?"; "Of what use is it all now?"; "If technology is to solve the problems of mankind, it also must be prepared to establish order in a world of chaos and strife."; "In a sweeping trend of total war, science must be ready to play its part."; and so forth.

To one who has spent over two decades in military research, these remarks are both gratifying and disturbing. It is encouraging to find so many engineers showing an awareness of the sociological implications in equipments for preparedness. On the other hand, it is somewhat disappointing to observe the "who cares?" attitude displayed by experienced American engineers concerning their colleagues' remarks as to the influences of this type of gear upon the social scheme of things. Now, more than ever before, our notions and concepts regarding national security and world peace depend upon the social significance we attach to military technology. Therefore, it is most essential that we think clearly and become articulate on the subject.

Because I believe that such informal table-talk bears directly upon our democratic processes as well as scientific achievements for the common good, I should like to elaborate upon some of the statements.

The basic premise put forth was that technical preparedness is a grim necessity, just as a well-planned community requires an effective fire-fighting machine. Both the nation and the community hope and pray that no occasion will arise to make use of its "superior" equipment. Yet, to provide a sense of security among its people, the equipment must be maintained in the best working conditions and kept up to date. In our complex society, what evaluates the services rendered by an engineer or scientist who devises an effective fire extinguisher in relation to the one who perfects a new design in toasters? If the social objective of the creative technician is to ease the burden of man in his daily life, then each of these workers is accomplishing his mission. The first allays the dread of fire while the second eases the mind regarding the possibilities of peptic ulcers.

Some of the members who took part in the discussion wondered whether the jobs were worth doing from the long-range scientific and engineering point of view; also, in the light of individual motivation and public welfare. These gentlemen should recall and contemplate a few thoughts which were tossed about the luncheon table:

1. The job had to be done, still has to be done for the good of all, and we may as well do the best job of which our country is capable.

2. In exploring and solving a technical problem, irrespective of the use to which the ultimate product is put, the scientist and engineer are contributing to the common fund of human knowledge.

3. Finally, and more specifically, in 1915, Professor Langevin at the University of Sorbonne, conceived the sonar transducer, which Captain Rawson Bennett mentioned, to combat the *U*-boat menace at the time. By this war effort he initiated and made possible today's general application of ultrasonics and the "strange new uses for sound" described in the September *Atlantic Monthly* by Harland Manchester.

ELIAS KLEIN

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NEW BOOKS....

"Lessons in Arc Welding." The third edition of "Lessons in Arc Welding" has been revised so completely that it amounts to almost an entirely new book. The book includes 58 lessons illustrated by 228 photographs and drawings which will assist both new and experienced welders. A section on questions and answers can be used for quizzes and self-examination. The book sets forth in simple language the practical instruction based on the experience of Arthur Madson, head instructor in the Lincoln Arc Welding School. Fundamentals of the method of joining metals by the fusion principle and new information such as new procedures used with large electrodes, newest electrodes and their use, lessons on pipe welding, and data on qualification of welding operators are included. The Lincoln Electric Company, Cleveland, Ohio, 1947, 158 pages, cloth-bound, $6^3/_4$ by $8^3/_4$ inches, 50 cents postpaid in the United States, 75 cents elsewhere.

"Mathematical Tables from Handbook of Chemistry and Physics." The eighth edition of "Mathematical Tables" is similar in content although different in form from the mathematical section of the current edition of the "Handbook of Chemistry and Physics." The book originally was intended to provide adequate means for the ordinary computations of chemistry and physics, and in response to the increasing demand for the small volume it has been published in desk size which is better suited for constant use. Modified type and spacing made possible by larger pages increases legibility. Explanations of the nature and uses of the various tables have been extended and collected at the front of the volume. Compiled by C. D. Hodgman. Chemical Rubber Publishing Company, Cleveland, Ohio, 1946, 366 pages, cloth-bound, $5^1/_2$ by 8 inches, $1.

"List of Inspected Electrical Equipment—May 1947." The list contains summaries of reports on electric equipment which has been examined with reference to fire and accident hazards and for conformity with the provisions of the National Electrical Code applying to its installation and use. The listing is divided into two parts, one of which is for equipment for use in ordinary locations, and the other for equipment for use in hazardous locations. To use the list the classification of the article first must be determined after which its location may be found through reference to the index. Immediately preceding the first manufacturer's name, under the classification there is printed "Label Service," "Reexamination Service," or "Special Service." These headings refer to the Underwriters' Laboratory service under which the device in question is covered. To facilitate location of devices by trade name or trade mark a list of such markings is included in the book. Underwriters' Laboratories, Inc., New York, N. Y., May 1947, 481 pages, paper-bound, 6 by 9 inches, available without charge when requested.

"The Managements Leader's Manual for Operating Executives, Supervisors and Foremen—Number One." This book was designed primarily for operating executives, supervisors, and foremen whose management roles it emphasizes. The purpose of the manual as pointed out in the foreword is to bring the American Management Associations to more people—and to bring some of the best available information on human relations and operating problems to a large number who do not ordinarily have regular contacts with the association. The seven sections of the book deal with the management leaders' human relations responsibilities, management leadership in democracy, interviewing and counseling techniques, safe and efficient production, progressive training techniques, tests for the management leader, and a section on simplicity—the key to success. The volume is designed for individual reading to further knowledge of the management structure for supervisory conference training through chapter-by-chapter discussion, as a desk manual for executives and supervisors, and for general reading as an introduction to practical management. Edited by J. O. Rice and M. J. Dooher. American Management Association, New York, N. Y., 1947, 192 pages, spiral bound leatherette, 6 by $8^1/_2$ inches, $3 to nonmembers, $2.75 to members of the American Management Association.

"Anatomy of Depreciation." The one exception to standardization of public utility accounting in the United States relates to depreciation, and efforts have been made from time to time to eliminate

this exception and to apply the same precision to depreciation as to other phases of accounting. Utilities have criticized the proposed degree of refinement as not having an adequate factual basis because the rapid growth of the industry and radical changes in the character of property units make impossible any precise forecasts of the periods of usefulness of equipment now in service. There is, however, no serious question as to the need of providing for the retirement of property in some orderly manner during its years of service. The book presents a history of the development of depreciation accounting and summarizes present conflicting views, all of which is supplemented by such available facts which may be helpful in pointing to a reasonable solution. Two distinct accounting procedures are presented, one of which assumes that the progress of depreciation can be determined with needed accuracy, and the other which assumes there is a lack of definiteness and regularity in the incidences of depreciation, and that the maintenance of the required reserves through adjustable current charges is the logical final step instead of the initial one. By Luther R. Nash (M'16) who died recently in Danbury, Conn. Public Utilities Reports, Inc., Washington, D. C., 1947, cloth-bound, 214 pages, 5³/₄ by 8¹/₄ inches, $5.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

PICAO (Provisional International Civil Aviation Organization). Document 2553 COT/26. Final report, first session, special radio technical division. Apply to Secretary General of PICAO, Dominion Square Building, Montreal, Quebec, Canada, 1947. 84 pages, diagrams, maps, tables, 10¹/₂ by 8 inches, paper, 75 cents. In an effort to promote the standardization of radar and radio aids to air navigation, the PICAO requested and held demonstrations of the latest of such equipment from three countries to determine the most suitable for world-wide use. The proceedings of the subsequent session are reported in this document, indicating the substantial agreement reached in four categories: instrument approach and landing aids; short-range navigation aids; long-range aids; and aerodrome zone aids. A series of three charts shows the effective coverage of Great Britain under three different systems.

LAW FOR ENGINEERS AND ARCHITECTS. By L. P. Simpson and E. R. Dillavou. Third edition. By L. P. Simpson. West Publishing Company. St. Paul, Minn., 1946. 855 pages, 9¹/₄ by 5³/₄ inches, cloth, $5. The method of presentation used in this text is to state the fundamental principles of law in those branches which bear most directly upon the engineering profession and to illustrate these principles, where space permits, with cases in which an engineer, builder, architect, or owner are involved as parties. In the new edition some 70 cases have been added, most of which were decided after 1941. Particular emphasis has been given to the law of contracts with separate chapters devoted to its various elements. Standard forms of contracts and agreements are appended.

INJECTION MOLDING OF PLASTICS. By I. Thomas. Reinhold Publishing Corporation, Now York, N. Y., 1947. 534 pages, illustrations, diagrams, tables, 9¹/₄ by 6 inches, cloth, $10. The book is at once a simplified text for the layman, a handbook of technical data, and a complete survey of injection molding and the plastics industry. It contains charts of the physical properties of many plastics, the history and development of the industry, and information about the design, construction, and finishing of plastics products. Information is given on estimating costs and on safety practices.

RADAR ENGINEERING. By D. G. Fink. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 644 pages, illustrations, diagrams, charts, tables, 9¹/₄ by 6 inches, cloth, $7. This volume is designed specifically to acquaint engineers and technical workers in radio and electronics with new techniques, and special applications of old techniques, used in radio detecting and ranging of objects. It covers the theory and practice of radar technology, describes various radar systems, and explains in technical detail the design of specific apparatus. Dealing broadly with fundamental concepts, the book discusses such subjects as pulse generation and transmission, waveguides and transmission lines, and propagation of ultrahigh-frequency signals. Information also is given on the practical aspects of components, circuits, and structures used in radar equipment.

VISIBLE SPEECH. By R. K. Potter, G. A. Kopp, and H. C. Green. D. Van Nostrand Company, New York, N. Y., 1947. 441 pages, illustrations, diagrams, charts, 11 by 7¹/₂ inches, cloth, $4.75. Part 1 of this volume describes the electronic principles employed and the instruments which have been devised for the production of visible speech. Part 2 presents a step-by-step course of instruction in how to read visible speech. Part 3, after considering the interests of the deaf, proceeds to other practical applications of the principles of visible speech in phonetics, music, language study, physiological diagnosis, and so forth. More than 500 reproductions of spectrograms show all the sounds and important sound combinations in American speech, with many examples of words, phrases, and sentences.

YOUR CITY TOMORROW. By G. Greer. The Macmillan Company, New York, N. Y., 1947. 210 pages, maps, 8¹/₄ by 5¹/₄ inches, cloth, $2.50. This book gives a general history of the growth of cities and the methods used to combat decentralization, blight and slums, and threatened fiscal breakdown. A description is given of the efforts of the last 50 years to cope with the urban problem. Urban housing, the money problem, and plans for the future rehabilitation of urban areas are dealt with. Special mention is made of Boston's comprehensive plans for reorganization.

PAMPHLETS . . .

Analysis of Measurements. The original presentation of the analytical method contained in this pamphlet was made by I. F. Kinnard in technical paper 46-133, "Functional Analysis of Measurements," at the AIEE summer convention in Detroit, Mich., on June 26, 1946. Apparatus Department, General Electric Company, Schenectady, N. Y.

U. S. Patents on Powder Metallurgy, NBS Publication M 184. A comprehensive list of powder metallurgy patents representing more than a century of progress in this art. The information was obtained from a collection search of 2,253 patents, and classified in related groups with a short abstract for each invention, by Raymond E. Jager and Rolla E. Pollard. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 30 cents.

Geiger-Mueller Counters Applied to Mining (R1040). A four page folder outlining Geiger counter theory and details of construction and operation. Applications of the instrument in mining work are discussed thoroughly, including topics such as techniques with isotopes, use in pitchblende exploration, oil-well logging, and geological surveys. North American Philips Company, Inc., 100 East 42d Street, New York, N. Y., no charge.

Rubber Research and Technology at the National Bureau of Standards (NBS Publication M 185). A summary of the activities of the National Bureau of Standards in each of 13 fields of investigation relating to natural rubber, synthetic rubbers, and related materials. The author is Lawrence A. Wood. Superintendent of Documents, Government Printing Office, Washington 25, D. C., ten cents.

Electrical Characteristics of Quartz-Crystal Units and Their Measurements (NBS Publication RP 1774). Outline of the problem of measuring dynamic electrical characteristics of high-frequency quartz-crystal units with ordinary laboratory instruments such as radio-frequency bridges and Q meters. Measurement methods and techniques are given, together with relative merits and limitations. The authors are William D. George, Myron C. Selby, and Reuben Scolnik. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 15 cents.

Announcement of Changes in Electrical and Photometric Units (NBS Publication C 459). A short account of the development of the new international agreements on practical units of electricity and of light derived from the fundamental mechanical units of length, mass, and time. The magnitude and legal status of the new absolute units to be introduced as a result of these agreements are discussed. Superintendent of Documents, Government Printing Office, Washington 25, D. C., five cents.

Report of the 32d National Conference on Weights and Measures (NBS Publication M 186). A complete detailed report of the 32d National Conference of Weights and Measures, sponsored by the National Bureau of Standards and held in Washington, D. C., September 26–28, 1946. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 40 cents.

Basic Radio Propagation Predictions for September 1947 Three Months in Advance (NBS Publication CRPL-D34). Basic radio propagation predictions three months in advance with instructions for use. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 15 cents.